Iron and Steel Engineer

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J. F. KELLY, *Editor*

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"ELECTRIC TIMING DEVICES FOR PRODUCTION CYCLE CONTROL," Wm. Horko, Electrical Engineer, Henry Disston & Sons, Inc., Philadelphia, Pa.

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SATURDAY, MARCH 26, 1932

"LUBRICATION OF ROLL AND PINION NECKS," H. T. Anderson, Hills McCanna Co., Chicago, Ill.

EDITORIAL

"Acres of Diamonds"

Russell H. Conwell, a platform orator and pastor, delivered many popular lectures, one of them being "Acres of Diamonds." The theme and moral of this lecture are *"Opportunity is resting on your doorstep, not a thousand miles away."*

As an evidence that sometimes we are all inclined to visualize the green fields afar, and still be quite indifferent to the possibilities within our realm, may we quote the following letter:

Association of Iron & Steel Electrical Engineers,
1010 Empire Building,
Pittsburgh, Pa.

Dear Sir:

I have been in the United States for almost two years on engineering work in connection with Iron and Steel Mill Projects for the Russian Government.

During this time I have had the honor of membership in the Association of Iron & Steel Electrical Engineers for about one year, and now before leaving the U. S. A. to return to Russia, I want to express my appreciation of the value of membership in the Association.

I have enjoyed attending the meetings and inspection trips of the Association and have found them extremely interesting.

The files of the "Iron & Steel Engineer" contain a wealth of information of value to the engineer in the Iron and Steel Industry, the like of which I do not believe is available to any other industry in any part of the world.

In short, I believe that the Association of Iron & Steel Electrical Engineers is doing work which is of great value, not only to the members of the Association, but to the Iron and Steel Industry in general, and I believe that the Association deserves the most enthusiastic support of all its members.

With best wishes for the continued success of the Association, I remain

Yours truly,

P. L. LITVIN,
Electrical Engineer.

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Reversing Synchronous Motor Drives For Metal Rolling Mills

By E. T. PETRIK
Electric Machinery Mfg. Company, Minneapolis, Minn.

Presented before Association of Iron and Steel Electrical Engineers, Chicago Section, Feb. 17, 1932.

The purpose of this paper is to describe the application of a synchronous motor to a hot copper reversing mill. This application was made in the summer of 1930, and the unit has been in practical operation since then.

The mill is a single stand two-high mill, roll size 24" diameter x 44" long. This mill is used as a break-down mill, taking the hot copper ingots and rolling out to dimensions suitable for the finishing mills. The size of ingot and size of the stock leaving this mill varies, but a representative job would consist of an ingot approximately 12" x 4½" x 30" long, reduced to ⅜" thick by 16" wide, in eight or nine passes. The ingot enters the mill at a bright cherry red heat, and finishes practically black.

This mill was originally operated by means of a uni-directional synchronous motor having a rating of 400 H.P. 300 R.P.M. A double reduction gear gave a roll speed of 30 R.P.M. Fig. 1 shows the original motor drive. In this photograph the rolls are hidden by the motor. With this arrangement the operators passed the material back over the top roll after each pass.

CONDITIONS LEADING TO INSTALLATION

The main object of installing a reversing drive on this mill was the desire for increasing appreciably the output of the mill. All of the copper ingots passed through this mill and the copper capacity of the plant was limited by the maximum possible output of this mill. It became necessary to either install another mill or increase the possible output of the existing one.

Installation of a new mill involved relatively excessive expense and also called for floor space not readily available, near the furnaces. Consideration was, therefore, given to converting the mill to a three-high mill, which was found impracticable because it meant practically a new mill. The installation of a reversing drive seemed to be the simplest solution, and particularly since it was found that it would be unnecessary to make any changes in the reduction gears, or in the mill itself. It was recognized that it was universal practice on reversing mills to use D.C. motors. However, since this was entirely an A.C. plant, (with the exception of some very small D.C. auxiliaries), the installation of a D.C. drive involved; in addition to the D.C. motor, the installation of a relatively large M-G set for this one motor. The complexity and expense of such an installation, as well as the lack of conveniently available floor space for the M-G set, led to an investigation of the possibility of using an A.C. motor.

The common use of, and the excellent results with, synchronous motors for both copper and brass mill drives in this plant, made it rather a natural thing to consider the possibilities of the use of such a motor for reversing service. The very radical nature of such an installation was fully appreciated. However, a thorough study of the requirements of this mill, indicated that the nature of the load, the desired cycle of operations, and the time limitations imposed, could properly be handled by a synchronous motor designed for such service. Moreover, it was found possible to design such a motor to fit on the existing foundation without even changing foundation bolts, and without changing the position of the coupling. This factor from a practical standpoint was quite important, because it was necessary that the change from one drive to the other be made with a very minimum time of shut-down of the mill. The Kva and power factor relationships were carefully worked out and the approval of the Power

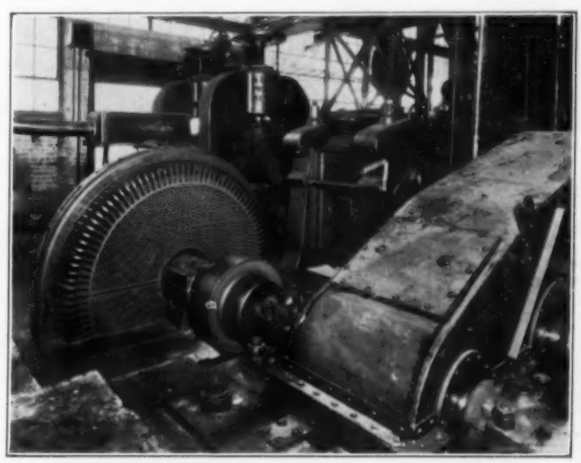


FIG. 1—Uni-directional Synchronous Motor Originally Used for Driving the Copper Mill.

Company was secured. Such approval was found possible because the drive represented a small part of the total load of the plant, and also because the total load of the plant was at a very high power factor.

MOTOR CONSTRUCTION

The motor is shown in Fig. 2 and Fig. 3. The first shows the same coupling connection shown by Fig. 1, which covers the original uni-directional motor drive. Both pictures show clearly the enclosures, the ventilating fan and motor, and the ventilating ducts leading to the roof.

Apart from the basic problem of designing for suitable torque characteristics, one of the principal problems was to limit the operating temperatures of the various motor parts. Since under repeated reversing, the motor operates for a considerable portion of the time on the cage winding, it was necessary to design so as to hold the cage currents to a

minimum consistent with getting the required torques. Fig. 4 shows the rotor, and it will be seen that the end rings are formed of a number of fins welded to the cage bars. These fins form a honeycomb structure with a large area of radiation surface, which permits rapid dissipation of heat from the cage structure. By this means the temperature of the cage winding is held to a safe value.

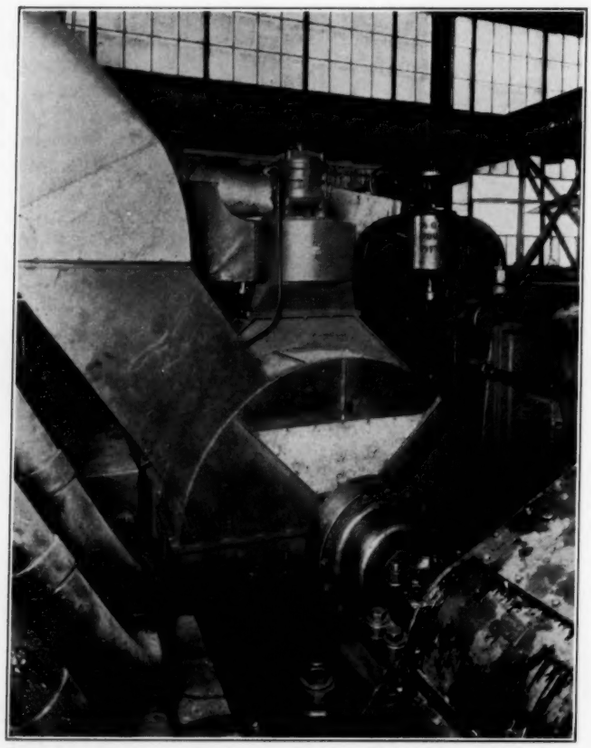


FIG. 2—Reversing Synchronous Motor Showing Setting in Same Position Originally Occupied by Motor in Fig. 1.

The field coils are strap wound, and asbestos insulated. To prevent undue heating of the field pole cores, they are made up of thin sheet steel instead of the usual 16 gage sheets. Ample ventilating spacers are included in the pole iron. To guard against loosening of cage windings, they are rigidly anchored to the fan blades. Likewise, the field coil backings are arranged with bolts so that the coils can be readily tightened if any looseness should develop. Fan parts are bolted and welded for permanence.

The rotor spider is shown in Fig. 5. It is made up of steel plates, suitably bored, in order to get the required strength and dimensions with a very minimum of weight. A real effort was made to hold down the weight of the rotor, in order to keep the WR^2 to a minimum so that quick reversal would be possible.

The stator is shown in Fig. 6, which shows the end covers removed. The stator frame is of fabricated steel, heavy box type section. The core is stacked on machined keys, with follower plates arranged for easy parallel tightening of the core. The section between the stator backplate and the core is large, permitting free movement of a rather large volume of air. Stator coils are "micatite" insulated, practically eliminating possibility of breakdown and permitting safe operation at higher than usual temperatures. This "micatite" insulation is formed by wrapping the conductors with many layers of mica sheet, and tightening and processing in such a way as to form for all practical purposes a thick solid section of mica. The slot insulation likewise is of mica, with combination mica and processed horn fibre slot wedges. End turns and coil connections are rigidly lashed together and also to bracing rings, which in turn are anchored to the frame.

Forced ventilation is obtained by means of a blower mounted on an opening on top of the stator frame. Clean air from the outside enters the motor through the ventilating ducts, shown in Figures 2 and 3, and the warm air is discharged through the blower. Suitable baffle plates within the enclosure, direct the air stream through the rotor spider, the field poles, the stator core and windings, and out through the blower. The natural fan action of the fan blades on the rotor contribute to this directioning of the air stream.

Complete enclosure of the motor as shown in Figures 2 and 3 was not found necessary for proper cooling. During the first few weeks of operation open end bells were used. Later it was found that copper dust and oil from the mill was being drawn into the motor, and therefore, enclosures were added which were arranged to tap clean cooling air from the outside.

CONTROL

Part Winding Starting:

Before describing the control used on this reversing motor, it would seem in order to briefly dis-

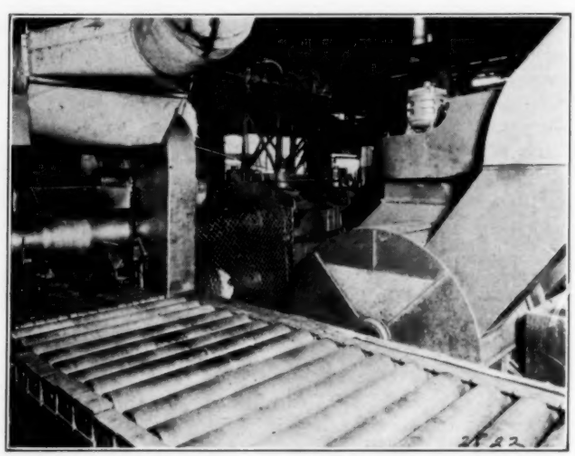


FIG. 3—Reversing Synchronous Motor Showing Mill Stand and Roll-Out Table.

cuss the so called "Part Winding" principle for starting motors as originally introduced by our company. This starting system is based on the fact that if one of two parallel properly distributed windings on the stator core is connected to full line voltage, the impedance of the one winding is appreciably greater than that of the two in parallel. Thus, we have a simple method of reducing the starting Kva as compared to other starting systems in which the whole stator winding is connected to line through an auto transformer, reactor, or by other means.

The effective impedance of a two-parallel-circuit

stator winding is dependent somewhat on the distribution of the coil groups on the core. However, the use of one circuit of a two-circuit winding gives ordinarily from 56% to 72% of normal full voltage starting torque and Kva, which is approximately equivalent to starting on the 75% to 85% tap on an auto-transformer.

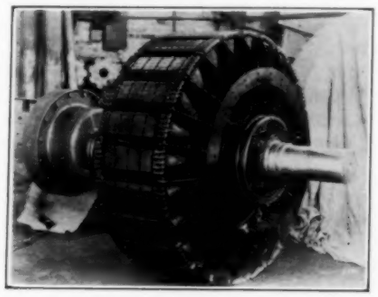


FIG. 4—Rotor, Showing Details of Cage Winding Construction.

FIG. 5—Rotor Spider. Note Steel Construction; also Provisions for Effective Ventilation.

FIG. 6—Stator Frame with Coils Assembled, Showing Nine Leads for Part Winding Starting.

This two-parallel-circuit principle can be carried further by making use of three or even more parallel circuits. Thus, starting with a number of increments can be obtained. In the reversing motor, three parallel circuits are used, there being nine leads from the motor. The effect of starting on one winding and then paralleling the two other windings one after the other, is clearly shown in Fig. 7. It will be noted from this oscillogram that the time increment between closing of contactors is very short, i. e., about six cycles or one tenth seconds. This is accomplished by electrically interlocking the control circuit of No. 2 contactor with the main contacts of No. 1; likewise by interlocking the control of No. 3 contactor with the main contacts of No. 2. It must be remembered that these increments must of necessity be very short, in order to permit rapid reversal of the motor for fast mill operation.

The principal object, therefore, of starting by means of three parallel circuits, is to cut down on the current handled by each contactor and thus cut down on contactor maintenance. Actually, these contactors operate for months without touching the arcing contacts.

The control board is made up of four panels, as shown in Fig. 8. Panel No. 1 includes the meters, protective relays, operating relays, indicating lights, field contactors, etc. Back of this panel is mounted the main 3 PST line oil switch. On the other three panels are mounted the forward and reverse operating contactors.

The main power circuits and switching are shown in Fig. 8-A. One leg of each star is connected to the line through one pole of the main line oil switch. During normal operation, this switch is kept closed, and this leg of each star is, therefore, continuously connected to the line. For "forward" operation the three "forward" air break contactors

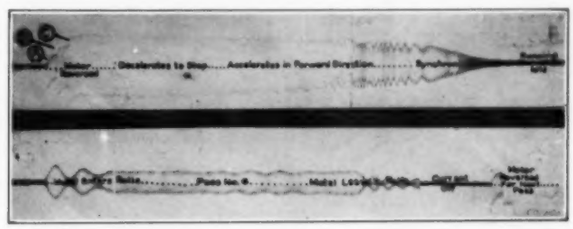


FIG. 7—Oscillogram Showing Complete Cycle of Reversing Operation.

(two pole each) connect the other two legs of each star to the line through the other two poles of the main oil switch. Likewise, for "reverse" operation, the three "reverse" contactors connect the other two legs of each star to the line.

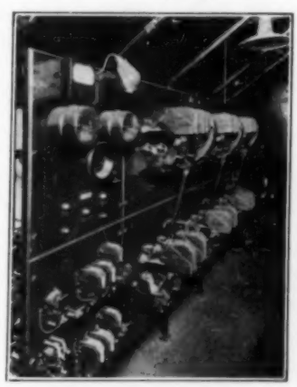


FIG. 8—Control Board Showing Interlocked Reversing Contactors.

Referring to Fig. 8, the three contactors on the top panel sections are the FORWARD contactors, and it will be noted that they are mechanically interlocked with the three bottom, or REVERSE contactors. As an additional precaution, they are likewise electrically interlocked.

The field excitation is applied when the motor reaches the proper speed by means of the field response or "frequency" relay. Two field switches and synchronizing relays are provided, one for FORWARD and the other for REVERSE Operation. The only reason two are provided, is in order to cut down on the duty of each and minimize field switch maintenance.

Indicating lamps at the panel show "forward" or "reverse" operation, availability of excitation

voltage, motor operating on cage winding, motor synchronized, etc.

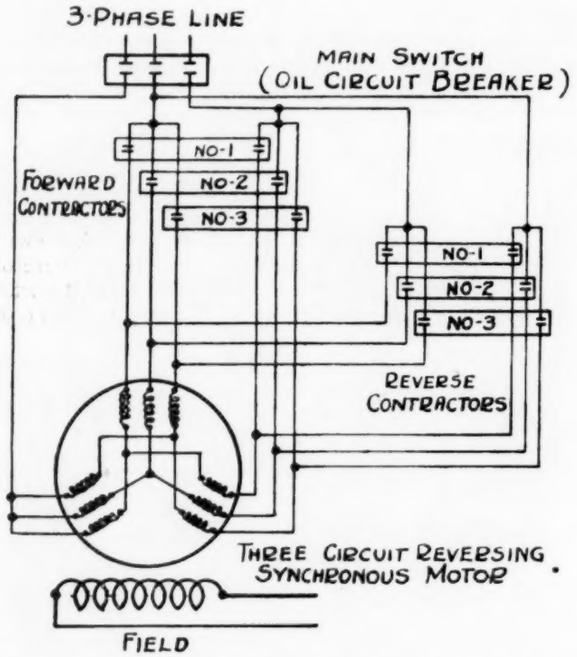


FIG. 8A—Power Wiring Diagram Showing Arrangement of Part Winding Circuits and Reversing Contactors.

The motor is controlled from the mill by means of a "drum" type master switch. A small indicating panel is placed near the operator upon which are mounted a full set of indicating lamps, and also an indicating wattmeter. Further, on each side of the roll stand, is mounted an indicating lamp, which shows when the motor is synchronized. In this way, no time is lost, and also the operators are warned against starting a pass before the motor is ready to take it.

MOTOR CHARACTERISTICS

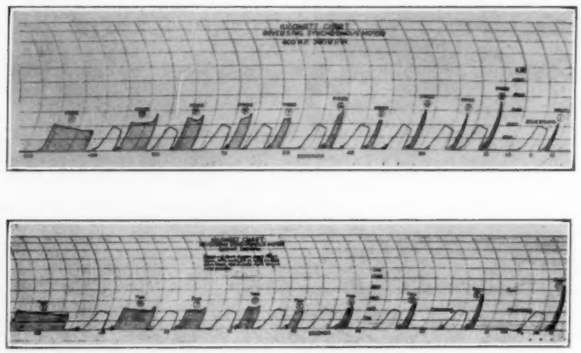
This motor has a nominal rating of 600 H.P. 300 R.P.M., 3 phase, 60 cycle, 440 volts, 1.0 P.F. The temperature rating of 50° was based on performing a specified cycle of operations, which covered a representative job for this mill. This job consisted of rolling an ingot 12" wide x 4½" thick x 30" long, down to ¼" thick by 16" wide in nine passes. Time of reversal is not more than five seconds, which means the full time between operation in one direction synchronized, to operation in the reverse direction synchronized.

Electrical efficiences, including blower losses are as follows:

½ Load	91.5%
¾ Load	94.0%
4/4 Load	95.5%

The temperature rise under actual mill operating conditions does not exceed 50° even during the summer. An indication of the ability of this motor to stand up under continuous reversal may be obtained from tests made just before the motor was coupled to the mill. Reversing the motor every ten seconds continuously for two hours, the core temperature was only 74°C, with room temperature of 35°C. The temperature had become stable and was not rising further. Under actual mill operating conditions, the heating would be very little, if any greater, because the heating effect of the load current would not be greater than that caused by the more frequent reversal in the above test.

The starting torque is ample for rapid acceleration of the unloaded mill. The reversing torque is found sufficient to take care of releasing the copper from the rolls, in the event it is stuck between the rolls for any reason. In other words, it is not necessary to release the pressure on the rolls in order to clear the mill. The pull-in torque is ordinarily not enough to synchronize under load, and therefore, it is necessary to make sure that the motor is properly synchronized before a pass is started. On light jobs where the peak load comes within the pull-in torque of the motor, it is possible to start the pass while the motor is accelerating, although this practice has not generally been followed. The indicating wattmeter at the mill has enabled the operator to keep fully informed, and with many jobs, it is used as a guide in setting the rolls between passes.



FIGS 9 AND 10—Recording K.W. Charts Showing Nine and Eleven Pass Jobs.

As noted above, this condition is readily noted by the mill operator by means of the signal lamps on the mill stand.

The pull out torque of 225% is sufficient to carry the maximum load peaks. This value of pull-out torque was decided on as a result of a careful study of the peak load requirements of the mill. As a general rule, it is only on the first two or three passes, that the peak load even approaches the pull-out torque of the motor.

CYCLES OF OPERATION

The recording Kilowatt charts shown in Figures 9 and 10 represent typical cycles of operation. In Figures 11 and 12 are developed the Horse Power load charts to correspond to the recording KW charts. It will be noted that the actual time of motor reversal is about 4½ to 4¾ seconds. When these charts were taken, no effort was made to have the operators hold down the time between passes to a minimum. This can be seen from the fact that the time intervals between finishing a pass and beginning of reversal varies in these charts from ½ second to 2.5 seconds. Likewise, the time intervals between synchronizing the motor and actual beginning of the next pass varies from one second

to fifteen seconds. It was found that holding down these two time intervals to a minimum, (2 seconds or less) was only a question of training the mill operators. This problem presented no difficulties.

Based on a typical ingot 12" x 4½" x 30" rolled down to 16" x ¼" in nine passes, the production from this mill was increased from a possible 20 cakes per hour to a possible 32 cakes per hour. Naturally, the increase is greater when rolling long lengths than when rolling short lengths.

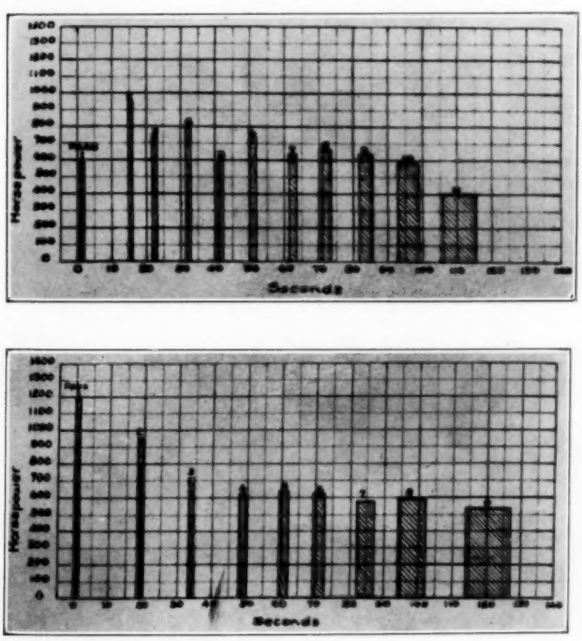
In actual practice it is found that for this particular type of work, faster reversal is not worth while because the time of reversal has proved to be equal to, or less than the time required to adjust the screwdowns, handle the metal, etc.

It will be noted from the Kw. charts that the motor is in synchronism roughly about 70% of the rolling cycle. Under properly controlled operating conditions, with delays held to a minimum, the motor is in synchronism about 62% of the time. Under any other conditions of operation, the motor will be synchronized a greater percentage of the time.

It is interesting to note that the efficiency of this unit during the pass is about 96%. When idling, the efficiency is about 75%. The power factor during the pass will depend on the load varying from somewhat leading at part loads to somewhat lagging at peak loads. During reversal it will be about 27% lagging.

GENERAL SUMMARY

Although no effort will be made in this paper to justify the use of the synchronous motor as against other types of reversing drive, a brief mention of some of the differences involved would seem in order.



FIGS. 11 AND 12—Developed H.P. Load Charts Corresponding to K.W. Charts Shown in Figs. 9 and 10.

In comparison with the direct current drive, including the necessary M-G set, the first cost of the synchronous drive was appreciably lower. The amount of floor space required was much less. The operating cost shows considerable savings because of the higher electrical efficiency. The maintenance expense is lower, due to simplicity of motor and control equipment. Reliability should be greater, again due to the simplicity and much fewer parts of the synchronous installation.

Against these apparent advantages, must be conceded the real advantage of the direct current drive which comes from flexibility of speed control, faster reversals, ability to start the pass before the motor has accelerated to top speed, etc. In this particular installation, however, the obvious advantages of the D. C. drive were not considered of sufficient value to balance the advantages of the synchronous drive.

As compared with the induction motor drive, the synchronous installation cost would possibly not differ greatly. The floor space would probably be comparable. The operating cost would probably be somewhat better for the synchronous motor because of somewhat better average efficiency. Reversing energy for the induction motor would probably be somewhat lower, but on the other hand the idling cycle and pass cycle losses of the synchronous motor would be lower. Simplicity of both motor and control would be rather in favor of the synchronous motor. Reliability and maintenance should be comparable.

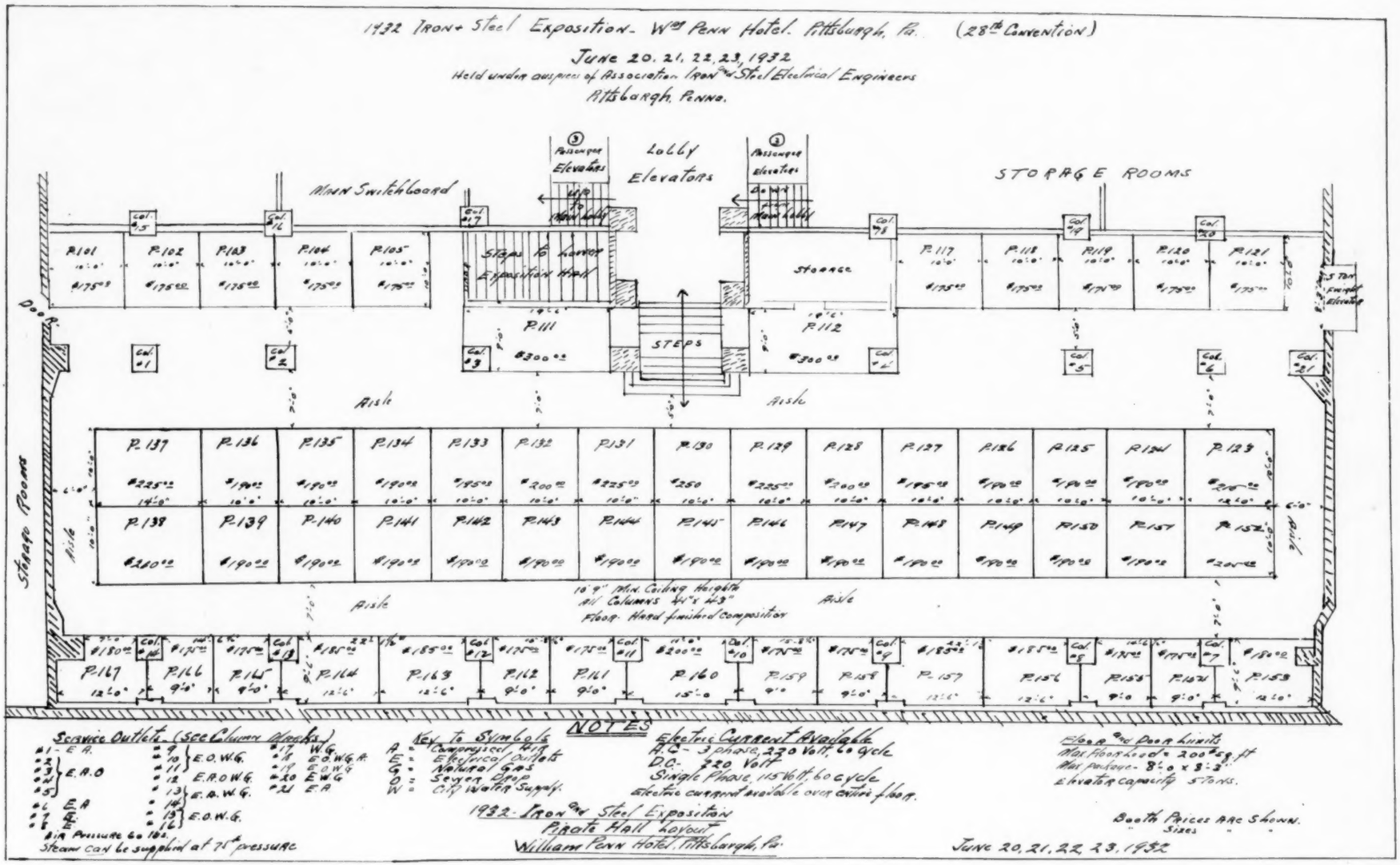
Really, a full and thorough comparison of the two types of A-C drives was not available on this job, since the induction motor was not offered by any manufacturer.

In conclusion the writer's aim has been to call attention to the severe duty imposed on this synchronous motor, and control, and its ability to stand up well under such severe duty. There is no effort whatsoever to suggest that the synchronous motor is ready for general application to reversing stands in the steel mills, or even in the non-ferrous mills. It is believed, however, that there will be some reversing drives, where the conditions of mill operation, plant layout, etc., are such that the synchronous motor may be best adapted.

There is still the feeling among some engineers, that the synchronous motor with its automatic control, is complicated, delicate, and bothersome piece of equipment requiring more than ordinary supervision and maintenance. It is the writer's fond hope that stories about synchronous motors successfully standing up under duties which would be considered severe for any type of motor (and there are many such synchronous installations) will help dispel such beliefs. Also, that such stories will help impress forcibly the fact that the common synchronous motor applications to mill auxiliaries, such as pumps, blowers, crushers, etc., as well as to uni-directional mill drives, where practicable, represent easy jobs for the synchronous motor.

IRON AND STEEL EXPOSITION

PITTSBURGH, PA.—JUNE 20 - 21 - 22 - 23, 1932


1932 Iron + Steel Exposition - Wm Penn Hotel. Pittsburgh, Pa. (28th Convention)
June 20, 21, 22, 23, 1932
Held under auspices of Association Iron and Steel Electrical Engineers
Pittsburgh, Penna.
Main Switchboard
Lobby Elevators
STORAGE ROOMS
Steps to Lower Exposition Hall
Storage
STEPS
Aisle
Storage Rooms
10'9" Min. Ceiling Heights
All Columns 4'1" x 4'3"
Floor: Hard finished composition
NOTES
Electric Current Available
A.C. - 3 phase, 220 Volt, 60 cycle
D.C. - 220 Volt
Single Phase, 115 Volt, 60 cycle
Electric current available over entire floor.
Floor and Door Limits
Max. Floor load = 200 lbs. per sq. ft
Max. package - 8'-0" x 8'-2"
Elevator capacity 5 tons.
Booth Prices are Shown.
Sizes
Service Outlets (see Column Marks)
Key to Symbols
A = Compressed Air
E = Electrical Outlets
G = Natural Gas
S = Sewer Drop
W = City Water Supply
1932 - Iron and Steel Exposition
Pirate Hall Layout
William Penn Hotel, Pittsburgh, Pa.
June 20, 21, 22, 23, 1932

Floor plan of the Iron and Steel Exposition held under the auspices of the Electrical, Mechanical, Combustion, Lubrication and Safety Engineering Divisions of the Association of Iron and Steel Electrical Engineers, Pittsburgh, Pa., June 20, 21, 22, 23, 1932. An Exposition of the developments in apparatus and equipment to process and produce Iron and Steel.

SYMPOSIUM
ON
DEVICES ACTUATED BY LIGHT

PRESENTED BEFORE THE

ASSOCIATION OF IRON AND STEEL ELECTRICAL ENGINEERS

▲

PITTSBURGH DISTRICT SECTION

WILLIAM PENN HOTEL — **OCTOBER 24, 1931**

"ELECTRON TUBES IN THE STEEL INDUSTRY," by L. F. Worden, Application Engineer, General Electric Co., Pittsburgh, Pa.

"BEHAVIOR OF PHOTO-ELECTRIC RELAY," by J. Farrington, Electrical Supt., Wheeling Steel Corp., Steubenville, Ohio.

DISCUSSION PRESENTED BY

T. R. RHEA, General Electric Company, Schenectady, N. Y.
H. L. WILCOX, Engineering Dept., Electric Controller & Mfg. Co., Cleveland, Ohio.
C. F. BARRY, United Engineering & Foundry Co., Pittsburgh, Pa.
J. HOUSSMAN, Mechanical Engineer, Great Lakes Steel Corp., Ecorse, Mich.
L. F. WORDEN, Application Engr., General Electric Co., Pittsburgh, Pa.
D. W. DEAN, Mgr. Control Section, Industrial Dept., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.
J. FARRINGTON, Electrical Supt., Wheeling Steel Corp., Steubenville, Ohio.
J. T. NICHOLS, Physicist, Research Laboratories, American Sheet & Tin Plate Co., Pittsburgh, Pa.
A. C. CUMMINS, Electrical Supt., Carnegie Steel Company, Duquesne, Pa.
G. BAUMGARTEN, Asst. Electrical Engr., Carnegie Steel Co., Duquesne, Pa.
R. LEECH, Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.
C. D. ROWELL, Electrical Engineer, West Leechburg Steel Co., West Leechburg, Pa.
J. W. BATES, Electrical Engineer, American Sheet & Tin Plate Co., Pittsburgh, Pa.
H. L. COE, Electrical Engineer, Carnegie Steel Company, Mingo Junction, Onio.

PHILADELPHIA DISTRICT SECTION

ENGINEERS' CLUB — **OCTOBER 31, 1931**

"THE APPLICATION OF ELECTRON TUBES IN THE STEEL INDUSTRY," by D. W. Dean, Mgr. Control Section, Industrial Dept., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

"SUPPLEMENTAL REMARKS AND DEMONSTRATIONS OF LIGHT SENSITIVE DEVICES," by Phillips Thomas, Research Laboratories, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

DISCUSSION PRESENTED BY

D. M. PETTY, Supt. of Service Division, Bethlehem Steel Company, Lehigh Plant, Bethlehem, Pa.
G. C. PFEFFER, Electrical Supt., Florence Pipe Foundry & Machine Co., Florence, N. J.
A. J. STANDING, Electrical Supt., Bethlehem Steel Company, Saucon Plant, Bethlehem, Pa.
G. J. WALZ, Asst. Elec. Supt., Bethlehem Steel Company, Steelton, Pa.
W. A. SMILEY, Research Engineer, Bethlehem Steel Company, Steelton, Pa.

CHICAGO DISTRICT SECTION

ELECTRIC ASSOCIATION AUDITORIUM — **NOVEMBER 16, 1931**

"VACUUM TUBES—THEIR INDUSTRIAL APPLICATIONS," by W. C. White, Engineer of Vacuum Tube Engineering Dept., General Electric Co., Schenectady, N. Y.

DISCUSSION PRESENTED BY

A. J. WHITCOMB, Asst. Electrical Engineer, Freyn Engineering Co., Chicago, Ill.
W. C. WHITE, Engineer, Vacuum Tube Engineering Dept., General Electric Company, Schenectady, N. Y.
J. W. MURPHY, President, J. W. Murphy Company, Chicago, Ill.
J. H. WAGNER, Electrical Supt., Acme Steel Company, Chicago, Ill.
G. E. ADAMS, Asst. Elec. Supt., Youngstown Sheet & Tube Co., Indiana Harbor, Ind.
O. P. ROBINSON, Electrical Dept., Wisconsin Steel Works, International Harvester Co., South Chicago, Ill.
E. C. MARSHALL, Electrical Supt., Youngstown Sheet & Tube Company, Indiana Harbor, Ind.
J. M. ZIMMERMAN, Engineering Dept., Westinghouse Electric & Mfg. Co., Chicago, Ill.
H. D. SANBORN, General Electric Co., Chicago, Ill.
W. J. RANNELLS, Electrical Dept., Illinois Steel Company, South Chicago, Ill.
F. A. WILEY, Electrical Supt., Wisconsin Steel Works, International Harvester Co., South Chicago, Ill.
H. G. HAUGE, Supt. of Maintenance, American Sheet & Tin Plate Company, Gary, Ind.
R. O. HERBIG, District Mgr., Reliance Electric & Engineering Co., Chicago, Ill.

The Application of Electron Tubes In The Steel Industry

By D. W. DEAN
Manager of Control Section, Industrial Department, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

Presented before Philadelphia Section of Association of Iron and Steel Electrical Engineeds, Oct. 31, 1931, Cleveland Section, Dec. 11, 1931.

Introductory:

The general popularity of radio equipment has taken the vacuum tube, or more broadly speaking, the industrial tube, out of the realm of mystery. The industrial engineer today does not smile and shake his head when it is suggested his problem can be solved through the use of tubes, but as a matter of fact he is usually ahead of the electrical manufacturer and is coming to us with the suggestion that some particular application can be more efficiently handled through the use of tube devices.

In discussing the application of non-radio electron tubes in the steel industry I intend to first very briefly discuss the historical background of tube developments and the operating principle of different kinds of tubes. I will then discuss typical industrial and steel mill applications that have been made of electron tube devices, and finally we will consider other applications that are possible in the steel industry.

Historical:

A little more than fifty years ago Thomas A. Edison, while experimenting with his incandescent lamp, was having trouble with frequent failure of the filaments at the ends. His investigation showed all the failures occurred at the positive end of the filament. He constructed a special lamp in which he placed a plate terminal, and he discovered current would flow when he completed a circuit from the plate terminal to the positive end of the lamp. There was no current flow when the circuit was made from the plate to the negative terminal. This was the first observed flow of electron current. Thus, as frequently happens, the patient investigation of a trouble led to discoveries on which a large and rapidly growing industry is based. However, more than twenty years passed before practical use was made of Edison's discoveries along this line. Fleming's use of this principle in 1905 in the "Fleming Valve", or radio detector, was rapidly followed by many important developments as shown by the "Family Tree" for the electron tubes.* Fig. 1.)

Some Types of Electron Tubes:

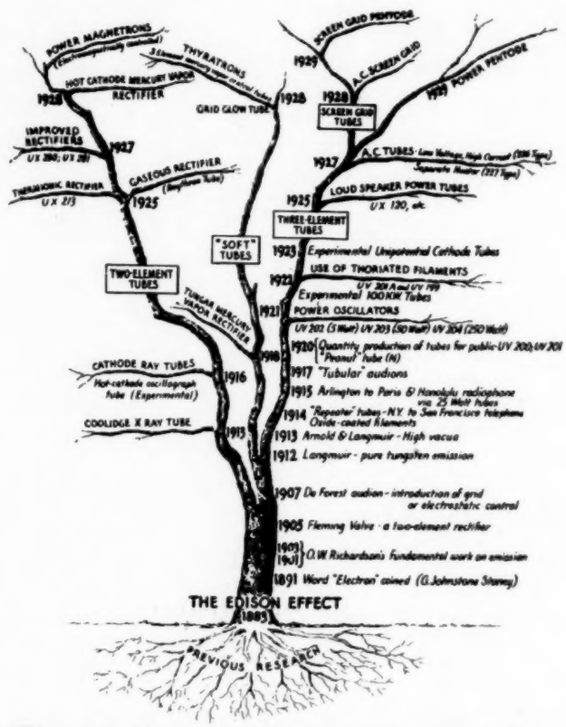
The types of electron tubes most frequently used in industrial applications may be listed as follows:

1. Phototube.
2. Three element thermionic tubes.
3. Grid-glow tubes.
   a. Neon filled
   b. Mercury vapor
   c. Mercury pool

* This "Family Tree of the Thermionic Tubes" is from the May, 1930, issue of Electronics.

Phototube:

The phototube is a two element tube which may be a vacuum tube or a gas filled tube, in which the cathode is treated, or "coated", with a light sensitive



The family tree of the thermionic tubes

FIG. 1—The Family Tree of the Electron Tube (From Electronics By Permission.)

substance such as sodium, potassium, caesium or a similar alkali metal. When light falls upon the cathode and with voltage properly applied to the tube current flows by electronic emission from the sensitized cathode to the positively charged anode.

The amount of current that flows is a function of the amount of light that falls upon the sensitized cathode. The phototube of the gas filled type will pass a much greater current than the vacuum tube type as a result of gas ionization. (Fig. 2.)

The phototube as just discussed functions by photo-emissive effect; that is, when voltage is properly applied and light falls upon the treated cathode current flows by electronic emission. Two other classes of photoelectric effects should be mentioned as devices depending on these effects are being offered commercially and there may develop a limited

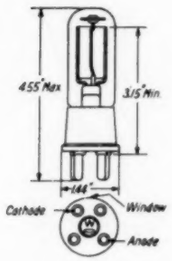
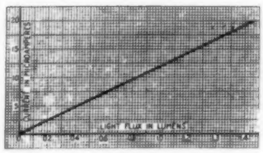


FIG. 2—Relation Between Phototube Current and Light Intensity.



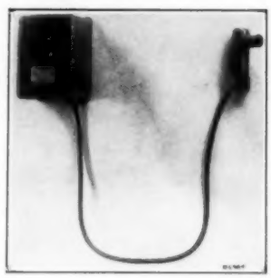


FIG. 3—Typical Light Relay with Extended Phototube.

field of application for them. One of these other classes of apparatus depends on photo-conductive effect, that is a change in ohmic resistance of a substance produced by the action of light. The selenium cell is typical. The third class of apparatus depends on photo-voltaic effect, that is, the generation of an electro-motive force caused by the action of light. Copper oxide is a typical substance used in this class of cell. The phototube is so simple in construction and has been developed to such a rugged state that it will undoubtedly be used for practically all applications based on photo-electric effects.

The current passed by the tube is quite small, usually a few micro-amperes, and must be amplified in order to operate control relays. For some applications this amplification is accomplished with the three element tube, and for others the grid-glow tube is used.

Three Element Thermionic Tubes:

Undoubtedly most of the audience are familiar with the three element thermionic tube, but in order to make this story complete, I will ask that you pardon the following brief description of these tubes.

The three element thermionic tube has a filament, a plate, and a grid. Their operation depends on the emission of electrons from the heated filament to the positively charged anode, which is the plate. The grid is placed between the filament and the plate to control the flow of electrons. When a negative potential is established on the grid its own charge opposes the charge on the plate and decreases the flow from the filament, and the proper negative grid bias will completely stop the flow of electrons from the filament. Typical characteristic curves have been shown so frequently that they are familiar to most engineers and will not be repeated here.

The three element tubes such as just described find their chief use as amplifying tubes. Also since the electron flow will take place only from the heated filament, to the plate the tube is used as a rectifier.

The Grid-Glow Tubes:

The grid-glow tube is composed of three electrodes: an anode, a cathode, and a grid. When left free the grid will assume a high negative potential with respect to the anode and the tube will not break down or pass current. If a conducting element, such as a grid resistor, condenser, or phototube is connected between the grid and the anode, the charge will leak off of the grid and the tube will break down and pass current. Once the anode current is started the grid has no appreciable control in that it cannot limit or stop the flow of current. The flow of current must cease long enough for the gas in the tube to deionize before the grid can regain control. (Fig. 4.)

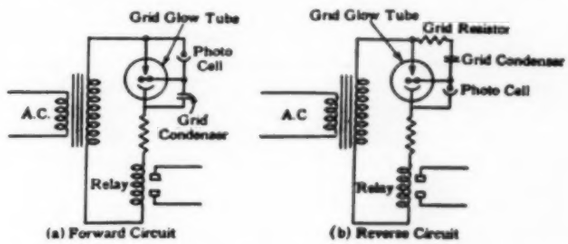


FIG. 4—Typical Circuit of a Phototube Controlling a Grid-Glow Tube for Use on Alternating Current.

The grid-glow tube is used as a relaying device in phototube applications as the circuit can be arranged so the grid-glow tube permits a certain current to flow, or no current to flow, depending on the amount of light on the phototube. The grid-glow power tube is also being used for variable voltage control of direct current motors from an alternating current source, as well as for field control of direct current motors. Grid-glow power tubes are rapidly becoming of increasing importance in motor control.

Amplification:

As previously mentioned the current of the phototube, which is of the order of a few micro-amperes must be amplified to operate control circuit relays. Either the grid-glow tube or the three element amplifier tube may be used. Typical circuits can be found in the various trade magazines, or in publications that can be obtained from various manufacturers. Several manufacturers now have commercial assemblies of the phototube and amplifying tube in one rugged case. (Fig. 5.)

Steel Mill Installations of Electronic Devices:

We will now consider some installations of electronic devices that have been made in the steel industry. Some installations in other industries will then be considered as they may suggest other installations applicable in the steel industry. And then we will review various steel mill departments as to the possibility for future application of electronic devices.

In one steel plant a flying shear is located be-

tween the intermediate and finishing stands of a 10" hot strip mill. This shear is to cut off the relatively cold front end of the bar before it enters the finishing stands. Formerly an operator was necessary to start the shear when the strip was in the proper position, so as to cut off a definite crop length. Now a phototube equipment automatically starts the shear. An adjustable time relay is used to determine the time interval between the interruption of the beam of light and the starting of the shear, thus compensating for changes in the strip speed, as the strip speed when it reaches the shear is adjustable from about 400 to 550 feet per minute.

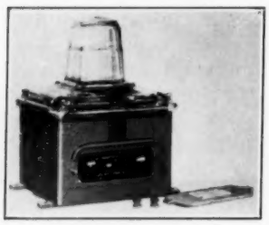


FIG. 5—A Lighting Control Unit for Turning "On" and "Off" Factory or Office Lights Depending on the Natural Illumination.

At a steel plant in the Pittsburgh District considerable trouble was encountered with the flag switch used to complete the proper circuit for recording the bloom temperatures as the bloom came opposite a permanently located Ardometer. On account of excessive maintenance with various types of flag and trigger switch devices, a man was stationed at a master switch and his only job was to operate the master switch for each bloom. The job was monotonous, and the operator would become careless and occasionally fail to function. A phototube with the required amplifier unit and relays now does this job in a reliable manner at considerable savings.

In a Chicago steel mill the soaking pit crane operator opens the soaking pit cover from his crane cab through the action of photo-electric equipment. When the crane is over the soaking pit from which the operator desires to lift an ingot, he steps on a foot-operated pushbutton which will momentarily illuminate a "light" box, the length of this light box being equal to the maximum bridge movement when the tongs are in the pit. Opposite the "light" box is a phototube unit with amplifier, and when the light strikes the phototube the cover opens. As soon as the ingot clears the pit the operator again steps on the foot-operated pushbutton to illuminate the light box and the pit cover then automatically moves to the closed position. (Fig. 6)

A number of other steel mill applications of photo-electric equipment have been made, such as skip hoist limit stops, stock bin level indicators, spotting of material in reheating furnaces, etc.

Let us consider a few typical installations in other industries as they may suggest applications to the steel mill engineer.

A number of applications have been made in the paper industry. In one case cellophane paper for wrapping cigars is cut to the proper length through the action of a phototube unit when the cigar band that is printed on the paper interrupts a beam of light. In another case a rotating flying shear cuts paper to definite length by a rather ingenious scheme of control. A series of equally spaced slots are cut along the edge of the paper. A rotating disc geared to the shear "heads" has two slots so arranged that the slot in the paper will not coincide with the disc slots when the paper is traveling at the proper speed. When the paper travels too fast a beam of light will pass through the slot in the paper and a slot in a rotating disc geared to the rotating shear heads, and the control will function to decrease the paper speed. Likewise when the paper is too slow the light will pass through the slot in the paper and a second slot in the disc and speed up the paper. By this means the paper is cut into equal length strips.

On a tire production line it is desired to open a valve for a spray treatment as the tire passes a nozzle. The tire stands vertical. It has been suggested that a magnet valve be controlled by a phototube to automatically control the spray. When the leading portion of the tire interrupts the beam of light, it is a simple matter to start the spray. But the light beam is quickly re-established through the hole in the tire, the tire standing vertical, but the spray must continue until the trailing edge or portion of the tire has passed the spray. This is easily accomplished. The first interruption of the

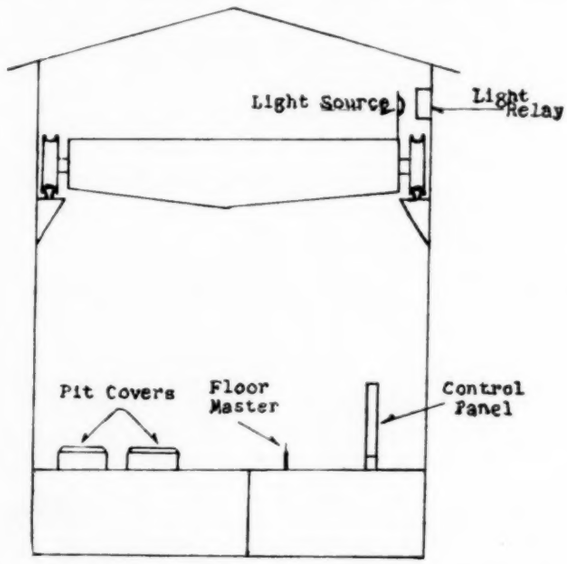


FIG. 6—Arrangement of Phototube Equipment for Operating Soaking Pit Covers.

light beam starts the spray, and a holding circuit is established so that the spray continues when the beam is re-established. The second interruption to the beam of light closes the valve, and resets the circuit for the next cycle.

A number of installations for sorting improperly labeled packages and for counting have been made.

Most operating engineers are familiar with the use of photo electric equipment for smoke density recording. An application of similar equipment has been made in the bag house of a smelting plant, where a number of bags are suspended to filter and salvage the escaping ore dust. The photo electric equipment gives immediate indication of a broken bag or other difficulties which result in an increased amount of dust particles in the escaping flue dust.

Also in a smelter plant there is an interesting application of rectifier tubes to provide double wave

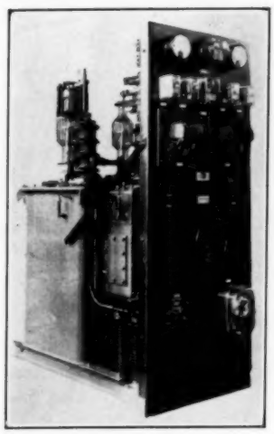


FIG. 7—Grid-Glow Tubes Used for Rectification of 80,000 Volts to Provide D.C. for Dust Precipitation.

rectification for supplying 80,000 volt D. C. for dust precipitation. (Fig. 7)

The daylight relay is a convenient assembly of phototube equipment for turning on the lights in factory, office or schoolroom, etc., when the natural illumination goes below a desired value, and turning off the lights when the natural light intensity returns to normal. Savings in lighting bills as high as 50% are possible, with additional savings in lamp life.

Motor Control by Grid-Glow Tubes:

Reference has been made to the increasing importance of grid-glow tube applications for motor control.

In one installation a one horsepower direct current motor is operated from an alternating current supply to drive a coil winding machine where the operator desires a very low speed when laying in the copper wire at the edge of the coil box, but where a high speed can be used while winding the layer across the coil. Two 6 ampere grid-glow tubes are used for variable voltage supply by a circuit which shifts the phase of the grid potential with respect to the anode potential. A foot treadle is used to accomplish the phase shift control. The direct current supply for the field and control circuit is obtained from two small two element rectifier tubes. The operator adjusts the field rheostat for the maximum desired speed, and then by means of the foot treadle the spool speed can be adjusted from almost zero speed to the maximum desired.

An inquiry indicates another interesting application. A 5-HP adjustable speed ventilating fan in a steel plant laboratory is frequently the only D. C. apparatus requiring the operation of a large motor-generator set over the week-end. The customer expects to install a grid-glow unit for operating this 5-HP adjustable speed direct current fan motor from the A. C. supply.

Other Possible Applications in the Steel Industry:

Discussions with various operating engineers and the many inquiries received for electron control devices indicate a possible field of application in the steel industry much greater than is now recognized. I have reviewed this field in general way and the accompanying list of possible applications has been prepared. This list is not intended to be complete but merely suggestive of what may be done.

Mechanical Consideration:

Industrial tubes have been developed to a suprising degree of ruggedness and dependability. Their use in automatic train control subjects them to severe vibration and rough handling. It is a proven fact that industrial tubes are satisfactory for severe applications. However, certain mechanical considerations must be kept in mind in making tube applications. The important mechanical considerations might be listed as follows:

A. The mounting should be such as to minimize effects of vibration, although modern industrial tubes are very dependable in this respect.

B. The mounting should be such as to give maximum protection from mechanical injury from cobbles and other external factors.

C. The tube devices should be so located as to permit convenient inspection and tube replacements.

D. The tube devices should be so located as to limit the temperature changes to a reasonable value. Humidity conditions should also be considered to prevent "fogging" of optical surfaces.

E. Eliminate as far as practical undesirable dirt, dust or vapor conditions.

The applications already made in the steel industry indicate that mechanical conditions will very seldom be such as to prevent application of industrial tubes to meet a given problem.

Conclusion:

Based on the number of applications of electronic devices that have already been made in the steel industry it is quite apparent there is a real economic field for such equipment.

In general there are two classes of applications to be considered.

A. Applications for which present equipment does not exist.

B. Applications where existing equipment of conventional design may be satisfactory, but where there is a possibility of improved service from electronic devices.

Typical of the first case is the counting of automobile traffic through the Hudson Tubes.

Typical of the second class of applications is the automatic starting of the flying shear in the strip mill to which reference has been previously made.

In either case the question is purely one of economics. For the first class of applications mentioned, it is a question of whether or not the need will justify the annual charge. In the second case it is a question as to whether or not the annual charge for the electronic equipment will be less than for existing conventional means for doing the job.

Certainly the interest the steel mill engineer is showing in this subject indicates there will be a wide field of application in the steel industry for electronic devices.

A Few Typical Industrial Applications:

Smoke density indication and recording.
Counting and sorting.
Paper cutting.
Paper break indication and recording.
Flashover protection.
Safety guards on hazardous machines.
Transparency measurement of paper.
Traffic counting.
Paper "white water" density indicator and recorder.
Door opening and closing.
Elevator leveling.
Elevator door control.
Boiler water level indication.
Machine limit switches.
Liquid level control.
Water softening, distilling and chlorinating processes.
Control of processes according to color and density.
Burglar and fire alarm systems.
Paper finish and gloss indicator.
Ramp traffic control.
High voltage rectification for dust precipitation.
Theater light control.
Mine door control.
Control of artificial lighting based on intensity of natural illumination.

Possible Steel Mill Applications of Electronic Devices:

A. Blast Furnace
1. Stock line indicators.*
2. Sinter bed thickness.*
3. Skip hoist limits.*
4. Stock bin level indicators.

B. Power House
1. Flashover protection.*
2. Smoke recording.*
3. Fire protection.*

C. By-Product Plant
1. Density and Translucency of liquids.*
2. Limit switches.
3. To make certain coke, pusher is in right position before ram can be started in oven.

D. Open Hearth
1. Temperature indication and recording of checker work.
2. Smoke recording.
3. Valve position recorder.

E. Blooming Mill
1. Soaking pit cover control.*

F. All Departments
1. Make proper ardometer connections for temperature recording of blooms, etc.*
2. Automatic starting of flying shears.*
3. Automatic looper control.
4. Automatic repeater control for loop mills.*
5. Automatic control of sheet mill tilting tables.
6. Automatic tension control for reel drives.*
7. Miscellaneous flag and limit switch purposes.*
8. Use of grid-glow tubes for armature or field control of D. C. motors from an A. C. source.*

* These applications or very similar applications have been made in steel plants or other industries.

Supplemental Remarks and Demonstrations of Light Sensitive Devices

By PHILLIPS THOMAS
Research Laboratories, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

Presented before Philadelphia Section, Association of Iron and Steel Electrical Engineers, Oct. 31, 1931.

Several of the gentlemen stated that they had not seen any of these light sensitive devices, and we thought they would be better able to work out possible useful applications of them, after seeing what they look like and how they work in other lines. I have several of them here, and shall be glad to show you how they operate; the actual applications I intend to show do not apply to steel mill work, but it is thought they will serve pretty well to start your imagination off in the proper direction.

But, before taking up light-sensitive devices proper, there is one entirely different thing I should like to show you. It should be of especial interest to your group. It is an alloy developed by the company with which I am associated, for use as core material in distribution transformers, radio set audio stage transformers, and in fact, any application where very high permeability, low core loss and low retentivity or coercive force is of advantage.

This alloy, called Hipernik, developed by Dr. Yensen, is possessed of all the enumerated good qualities. It is calculated that if used to replace the present silicon steel in the cores of distribution transformers, in ten-mil thickness, the no-load or magnetizing loss would be reduced to about one-third the present value.

The retentivity and coercive force are so small that the alloy can be demagnetized, magnetized and reversed by the earth's field alone. Here are two strips of Hipernik, about one-inch wide by eighteen inches long, by perhaps fourteen-mils thick. I hold one in my left hand, one in my right. Held horizontally, about at right angles to the North direction, they do not attract one another as you see

(overlapping adjacent ends about one-eighth inch.) They are not permanent magnets, with unlike poles in contact; when I turn one piece end for end in my hand, there is still no attraction or repulsion.

Now see what happens when I place them pointing in the North direction, at about the dip angle. Upon bringing near ends together, just as before, you see that there is quite a strong attraction between them. Turning one piece end for end, as you see, does not diminish the attraction,—in other words, the magnetic polarity of the piece just turned has been reversed by the magnetizing force of the earth's field alone. The same effect is obtained by reversing the other one. Furthermore, if I hold one piece at right angles to the North direction and the other remains pointed North, there is still attraction, though of course not as strong (about half as strong), and if I turn the North pointing piece also at right angles, all attraction has disappeared. I wanted to tell you about this new alloy because of its great potential value in the electrical industry.

Now let us return to the light-sensitive devices, and other so-called radio by-products: things which came as side lines, out of the very intensive cultivation as it were, of the three-electrode vacuum tube or radiotron as it is generally known. The three best known of these devices are the phototube or so-called "electric eye", and the hot-cathode and cold-cathode grid-glow tubes. The electric eye and its application has been masterfully discussed by Mr. Dean; associated with it is always some type of amplifying device, because the phototube itself passes an extremely small amount of current, even when brightly illuminated. This function of amplifying the result obtained from the phototube must be performed by amplifiers of the standard type,—multi-tube,—if the desire is to copy the wave form of variation of the incident light, as in sound recording and projection, television and the like; but, where one needs a simple relay action only, the bulk and expense of the vacuum tube amplifier can be eliminated by using a single follow-up tube, the cold-cathode grid-glow tube. I shall have more to say about this tube shortly.

Both the grid-glow tubes are primarily intended for relay action. They are "all-or-nothing" devices. The hot-cathode type is not normally quite as sensitive as the cold-cathode type, but it has a source of electrons, in its hot-cathode, which allows it to handle much more current than its smaller brother. Here is a piece of apparatus, a tool, of great usefulness, built around the hot-cathode grid-glow tube. It is called the "stroboglow"—a stroboscope using a grid-glow tube. Its use is the same as that of any standard stroboscope, but of greatly extended range. By discharging a condenser across the main terminals of the grid-glow tube, at intervals fixed by the varying potential of the grid or control electrode, we obtain extremely bright single flashes of light, each flash lasting a very short time. In this particular design, the condenser discharges in one-third of one micro-second, with an average discharge current through the Neon-filled glow tube, of about 240 amperes. The time and frequency of discharge is fixed either by a contactor attached to the shaft of the rotating or reciprocating piece to be examined, which makes one contact per revolution, or, when the machine is too small for such duty, by an audio oscillator or multi-vibrator whose frequency can be adjusted to the required value. This latter is the method I shall use here, and the piece to be examined is this small fan, whose blades have been flattened so that it rotates at about four thousand R.P.M.

I think you can see the effect better with the room lights out, so with your permission I shall endeavor to blow them out (blows upon a special apparatus, whereupon the room lights go out).

Now as the fan speed comes up, you can see several points at which it apparently stands still temporarily,—the sub-fundamentals,—and now finally it has apparently come to rest, and the letters on the blades can be read just as though the fan were really at rest,—although as you can hear, it is still running at normal or intended speed. (At this point a match was lighted and held near a phototube, at which the room lights came on once more).

We are very proud of this stroboglow as we call it. There are no end of feasible, useful applications. It can be used to check the spokes of rotating flywheels for flaws, or for agreement between actual and calculated strain under centrifugal rotational stresses; to determine the mechanism of erosion of the leading edge of propeller blades on airplanes, in rain or snow; to measure the frequency and amplitude of vibration of the blades of a steam turbine in operation, by insertion of a glass window in the steam chest; to check the slip of belts on pulleys under varying load, thus determining the proper tension. It is unnecessary to depend upon the eye alone when using the stroboglow: a magnifying glass may be used, just as in studying stationary articles,—or even a microscope unless the linear speed at point of examination is extremely high.

So much for the hot-cathode grid-glow tube. Perhaps I might mention in passing, that its action may be made quantitative if desired, by varying the phase between grid and plate voltage. In this way there has been developed a device which will control the brightness or amount of artificial illumination, continuously, as the amount of daylight varies in a room, thus maintaining a constant illumination which may be adjusted to the proper amount for the activity in the room.

In blowing out the room lights, and lighting them again with a match, I had another purpose besides pure entertainment: that was to bring out the extreme sensitiveness of the other, or cold-cathode, type of grid-glow tube, used as a relay. Standard electro-magnetic relays are or can be made fairly sensitive; the ratio between controlled and operating power, however, will not exceed one or two thousand to one. The little tube relay, the grid-glow tube, has a ratio of about 160 million to one. Of course it does not get this ratio on the output side; its output, while sufficient to operate a rugged electromechanical relay, is of the order of milliamperes only. Its excellence lies in the almost vanishing amount of power needed to cause it to operate. This breath grid is simply a device whose high resistance becomes lower when one breathes on it, due to condensation of moisture. The resistance change, in parallel with the grid control circuit, is ample to light the grid-glow, and the rest is a mere matter of standard relay application. The lighted match is held in front of a phototube connected in parallel

with the breath grid, and the change of resistance is again ample to light the glow tube.

The combination, phototube-grid-glow tube, as a unit, is finding wide industrial application, as stated and described at length by Mr. Dean. Many of the uses consist in simply causing some electrical circuit to open or close when light strikes or is cut off from the phototube. These are the simplest ones; and of course the action is the more reliable, the greater the difference between the amount of light incident in the "off" and "on" conditions. Concentrated research work, however, is continually improving the steadiness and permanence of calibration of the phototubes, and the life of the grid-glow tubes, so that the necessary change in light flux is being continually reduced. The wave length range in which the phototubes are most sensitive for the standard tubes, is just below the visible spectrum, but tubes are now being developed of considerable sensitivity in the ultra-violet, and in the lower infra-red; thus whole new fields of application are being made available.

One special application of much value is that of counting. Counting manufactured product on an endless belt; counting operations at a distance; as an example, counting automobiles entering and leaving the Holland tunnels from New Jersey to New York. Rather than bring along some commercial counting device, I have worked up a laboratory model which will count faithfully the number of impulses sent out by a standard telephone dialing outfit, and will prove that it has counted properly by operating electrical circuits by voice, which depend for accurate selection upon faithfully following the digits dialed. The transmitter, back on a table in the room, flashes a light once for each digit from its dial. This light falling upon the phototube in the receiving unit, here on the table, causes a telephone selector relay to notch up one for each flash received. Speaking into the telephone microphone on the sender causes the same light to shine upon the same phototube, but for a much longer time. This, instead of dialing, works whatever circuit has been connected by previous dialing. In other words, what we have here is a model telephone dialing station and associated central; and if the phototube-grid-glow tube unit counts correctly, we should be able to dial desired numbers (of which there are only six in this miniature "central"), and predict the result. For instance, I shall now dial the number corresponding to the room lights (dials a number). Now approaching the microphone, I say "OUT" (room lights go out). Dialing again I call for "RED" (red light appears on lecture table).

Thus you see that provided one does not make errors in dialing, one always obtains the correct number; notice that the sending box is equipped with its own power supply, in order that there may be no question of using wires to "fake" the response.

In closing, let me say that although many useful practical applications of light-sensitive devices have been and are being made, we are convinced that further knowledge of their possibilities by men in the field, and further development and broadening of their characteristics by the research staff, will make this type of apparatus, next to electricity itself, one of the most useful tools available.

Discussion

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D. M. Petty: It seems to me, to get the most out of the vacuum tube in the steel industry, we must use our imaginations to the limit. In the steel industry we have been in the habit of thinking that anything to be reliable must be rugged and simple. To my mind the greatest value of the vacuum tube as a control unit is the use of a connection to apparatus that has no weight and therefore no inertia. We know nothing has been discovered that is as fast as light, and Professor Einstein is able to prove nothing ever will be faster than light. Mechanical flag switches, in addition to the difficulties of making them rugged enough to stand the racket, always have a time element. With light control this is entirely eliminated.

So to my mind it is up to all of us to use our imaginations very freely. I think sometimes that those of us who are in the operating end of the game are a little prone to think that because something has not already been done, that it cannot be done. I believe it would pay us all to ask the manufacturers for apparatus that you have never heard of and give them what you might consider an impossible problem. Their own research men, I am sure, will welcome such requests, because it gives them a definite job to work on, and it is only by giving them things we think they cannot do that we will find out just what they can really do.

G. C. Pfeffer: I came here primarily to listen, but there is one question I would like to ask in regard to the temperatures of blooms.

Say that a piece of metal such as a bloom has a temperature of 1800 degrees and the light radiated from the bloom is sufficient to hold the relay open —is the tube sensitive enough that it will close when the temperature falls to 1780 degrees?

A. J. Standing: I am afraid there is but little I can add to this paper by way of discussion. I came here primarily as a student to find out just what the possibilities are and whether the operation of vacuum tubes has reached a point where it is sufficiently reliable to enter into our industry. We are operating very economically during this period of retrenchment and while we feel that we will come back we realize that many of our present economies will remain. I do not think that full operation will ever involve as many men as formerly and we must replace the previous forces by means of refinements in operation such as the adoption of vacuum tubes if they offer sufficient possibilities to justify their cost. The information now available on industrial applications of tubes is rather meager and one reason in coming to this meeting was to hear a review of actual applications, their operating costs and the reliability of these installations.

There is a question in my mind regarding the sensitivity of vacuum tubes to the variations in voltage of our plant sources with the thought that the demand for ideal conditions of voltage and frequency would add materially to the installation cost. Another point to consider is the ability of tubes to give good life when operating in conditions of vibration and dirt present in Mill locations. I believe,

however, that the time is coming when we will find economical applications for this type of equipment which will enable their production costs to be improved and I feel that Mr. Dean's talk is very timely.

We must look into the new problems that vacuum tube operation will present and make ourselves familiar with this type of apparatus and its application to Steel Mills and we should try and secure the necessary funds to permit of at least some local experimental work in our own plants. The normal Mill repairmen are not Ph.D's., and must be trained in the care of new types of equipment but I will say that their attitude toward new installations is one of interest and inquiry rather than of destructive meddling.

I congratulate Mr. Dean on his excellent paper and Dr. Thomas on his interesting demonstrations.

G. J. Walz: This paper to my mind is an outstanding example of the real benefits to be derived by attending the meetings of the Association. I have never seen one of these things; never have seen any literature on them, but I have learned something about them tonight. Although we do not have any in our place, I can see we are going to have some before very much longer.

W. A. Smiley: Inasmuch as I came here this evening as a guest, not expecting to participate in the discussion of this matter, I have no particular thought to present for your consideration. However, since we are gathered here to discuss amplifying devices, I feel that I might amplify a certain thought Mr. Petty has given us.

Mr. Petty suggests that it will be necessary that our imaginations be given rather free rein in that we may discern uses to which the vacuum tube may be profitably applied. My thought, based on a little over twenty years' experience with thermionic devices, is that there is hardly anything, in the nature of electrical control, which it is not possible to handle by means of vacuum tubes.

Mr. Dean has covered the photo-electric cell. There are many other applications, of course, which on account of time he was unable to discuss. We have already seen automatic power stations remotely controlled, generators synchronized, voltages equalized, and machines connected to their loads, and I feel that in the steel industry, in particular, the human equation can be greatly discounted by the use of vacuum tube devices in their many forms.

However, if in the course of the next several years we are to see a wide spread application of the "Genie of the Lamp," it is going to require not only a most careful study on the part of operating engineers, but more particularly it will require an almost limitless application of imagination, because many of the most profitable and economic uses will be for purposes now least anticipated by those unacquainted with the limitless possibilities of this tool.

Vacuum Tubes— Their Industrial Applications

By W. C. WHITE
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Presented before Association of Iron and Steel Electrical Engineers, Chicago Section, Nov. 10, 1931.

A vacuum tube may be classed as to: (1) Number of electrodes. A two-electrode is called a diode; a three-electrode tube a triode; and so on to include a tetrode and a pentode. (2) The content of the bulb, which may be high vacuum, gas or vapor. (3) The nature of the fundamental electrode, the cathode, which may be thermionic, photo-electric, mercury pool, or cold.

Practically any form of the many types of vacuum tubes can, for convenience, be classified by a combination of these three properties. For instance a bulb which is sold under the trade mark of "Tungar" is a gas content, hot-cathode diode. The screen-grid tube used so much in modern radio is a hot-cathode high-vacuum tetrode. The small tubes which are sold under the trade mark of "Thyratron" are hot-cathode, mercury-vapor triodes.

Fundamentally, the amount of current that can be carried through the vacuum in a hot-cathode, high vacuum tube is dependent upon what is termed the "electron emission" and the "space charge effect". In other words, to get current through a vacuum, the proper amount of electron emission to supply this current must be obtained, and also the proper voltage and the arrangement of electrodes must exist to permit this current to pass with the available voltage. The current through the tube may be limited either by not having sufficient electron emission or not having sufficient voltage to pass the described current.

The introduction of the grid is simply a method of controlling the space-charge factor.

A high vacuum tube has four features that singly or in combination make it a unique electrical device.

(1) Independency of frequency. Electrons are so rapidly moving that they will respond to frequencies of the order of several million cycles per second so that for most purposes the tube has no limitations in this respect.

(2) Continuous control. The electrons each carry such a small charge and move so rapidly that the current through the tube can follow a very complicated wave form smoothly, as distinguished from the step by step action that occurs in most other pieces of electrical apparatus. It is this feature that

has made the high vacuum tube so useful in long distance telephony and radio broadcasting.

(3) Voltage control. Relatively large amounts of current through the tube can be controlled by voltage on the grid without the necessity of furnishing any current to this grid. For instance, the electricity generated by rubbing a fountain pen with a piece of cloth, when applied to the grid, is sufficient to control relatively large amounts of power. It is this feature that results in the large amount of amplification that can be obtained by means of a vacuum tube.

(4) Rectification. Current passes through the tube only when the cold electrode is positive with respect to the hot electrode.

From the viewpoint of these four factors, it is readily seen why the high vacuum tube is such an important factor in radio.

The high vacuum tube, however, has for industrial application certain serious limitations. A very heavy price, in the way of power loss, must be paid for the current that it carries. As has been stated above, the current through the tube is governed by the electron emission and the space-charge effect, which later is simply another way of expressing the voltage loss in carrying the current through the tube. To make the cathode hot so that it will emit electrons requires electric power. This is of the order of 10 to 150 watts loss per ampere of current through the tube.

Considerable voltage is also required to carry the current across the space, the order of magnitude being several hundred to a thousand volts for one ampere. From this, it will be seen that currents of more than a few amperes cannot be handled economically by means of a high vacuum tube.

Therefore, it is apparent that the most promising applications in the industrial field for the high vacuum tube is in various control operations where some of the unique characteristics listed above, rather than its output, are the determining factors.

Taking up next the Thyratron tube, its striking characteristics are the greatly decreased amount of power required to heat the cathode, and a marked reduction in the large voltage drop which is characteristic of the high vacuum tube. This is brought about by the introduction of a very slight amount of gas or vapor into the bulb. This eliminates what we have termed "space-charge" which in reality is the mutual repulsion between the electrons due to their negative charge, that has to be overcome by the use of considerable voltage and which introduces a power loss. The positively charged mercury vapor or gas molecules mingle with the electrons, neutralizing this space-charge.

This neutralization of the space-charge allows a very different design of hot cathode. Instead of having to utilize what might be termed an open type of cathode for the electrons to leave the hot surface easily, it allows an enclosed type of cathode with just a few holes for the stream of neutralized and negative ions to pass through.

This means that the heat may be kept in and conserved, whereas the electrons and positive ions may be allowed to travel to the anode. This is accomplished by surrounding the hot cathode with heat insulation and heat reflectors, with only relatively small holes to allow the passage of the current.

By such means we only have to "pay" about one watt per ampere for our current through the tube, rather than the 10 to 150 watts per ampere.

Also, this neutralization of the space-charge which results from the introduction of mercury vapor or gas eliminates the high voltage necessary to pass the current through the space, and instead of a large voltage increasing with the amount of current to be carried, there is a constant voltage loss of only about 10 to 20 volts.

It is, therefore, apparent that for the handling of relatively high currents, such as we have in the broad field of electrical engineering, the gaseous type of electrostatically-controlled tube is much better suited than the controlled high vacuum type.

It is true that a Thyratron tube has certain limitations. As has been stated, the high vacuum type of tube can handle currents up to the frequency of a million cycles per second, whereas the Thyratron in its present form is limited to a few thousand cycles per second. Also the Thyratron cannot control direct current in the same simple way as the high vacuum tube; that is, it lacks the feature of "continuous control". However, it so happens that just as the high vacuum tube fitted remarkably well into the radio communication field, the Thyratron tube appears to fit admirably into the industrial engineering field.

As a good example of this, consider Radiotron UX-250, a high power loud speaker tube that was used to a considerable extent with some of the early dynamic speakers. A Thyratron tube built to about the same size and costing the same amount as this Radiotron will handle approximately 50 times the current.

These are the reasons which give us complete faith in the application of the Thyratron type of tube in the broad industrial engineering field to the same amazing extent that the high vacuum type of tube, developed around the pliotron idea, has dominated the radio communication and broadcasting field.

Discussion

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A. J. Whitcomb: We are certainly to be congratulated in having such a good speaker with us tonight. I feel as though I had been sitting in the lecture room of the Physics Laboratory at college, listening to an extremely interesting exposition by a clever professor. Mr. White has given us a very enlightening talk on what makes a vacuum tube work and has done it in such a way that we can all understand it and make use of it in our own fields of endeavor.

In connection with the Thyratron tube, the thing that puzzles me is why we don't use it more. This tube, as Mr. White has told us, delivers a variable potential direct current from a constant potential alternate current power supply. If that is the case, why don't we do away with contactors and resistors entirely and run all of our direct current motors from alternating current. Why can't we start mill motors, table motors and fan drives without con-

tactors, resistors and all the other paraphernalia that we have used for so many years. Mr. White showed us one tube capable of supplying 600 amperes. Can't we think that in the future we are going to be using tubes entirely in place of contactors and rheostats or is this one of the fields of application that the tubes do not fit into so well?

W. C. White: That is a good point. It is natural to suppose that when I said that we have a controlled rectifier, that is, ability to get a variable D.C. voltage with no rheostat loss, we should have no more need of motor generators to give us D.C. from A.C. However, when you figure out the relative cost under present conditions, you find that the rectifier, strange as it may seem, usually comes out more expensive than the motor generator. The reason is this: We have been making induction motors and D.C. generators for more than a quarter of a century. Rectifiers, particularly small types, are rather new devices. That is brought out very clearly when you compare the items as we naturally do. Go into a place where they make a motor, pick up a field coil or other part, and you are always impressed with the low cost of material and labor. That is true of most any device in any field that has been the subject of development for a great many years. However, in the case of rectifiers of a special nature that include such items as mountings for the tubes, and special little transformers to give the grid control effects, you are immediately impressed with how expensive they are. The reason is—there has not been a long time, intensive effort on cost reduction. It is difficult to get a large production without low costs. A rectifier is, fundamentally, probably a cheaper device than a motor generator set but it will take several years to get that to be actually the fact. As a result, the application of vacuum tubes in the industrial field and in mills is going ahead at first where some special condition, rather than cost for an exactly similar result, is the important factor. Applications like very special motor controls and jobs in welding where they have been using heavy contactors are places where good economy can be shown in comparison with existing costs; also on devices that have not been changed for years or in special cases where ordinary or standard equipment does not function satisfactorily or has certain bad defects. When it comes to kilowatts A.C. to kilowatts D.C., more work has got to be done on intensive development of the component parts. It is not an easy matter. The problem of a new device competing against an old one is a common thing. It will take a few years to build up the technique to get them to a point where they compare with present day devices. In the case of rectifiers which require transformers, that is in the case of A.C. voltages too high to supply the motor direct, then the thing does become competitive even under present conditions.

J. W. Murphy: What would be the life of the tube, delivering its full rated current? The hours of life, that is one question; the second question, it has occurred to me that it might be possible to operate these in parallel to deliver a greater total current. I wonder if that can be done? The third question, can the speeds on motors be controlled with variable voltage on the fields delivered from these tubes?

W. C. White: As regards life—the life is a matter of design. The electron emission falls off slightly with time. Therefore, it is under control as a matter of design.

As regards multiple operation—the thing can be done but a vacuum tube is like other devices, that is, the cost per K.W. goes down as you make bigger units. The cost of a vacuum tube is so many dollars per ampere and not per kilowatt. The tube is a current device and its cost within a wide range does not vary much with the voltage. It is usually more economical to use one large tube.

In the case of synchronous motor excitation—it is much the same as the case of which I spoke before. Fundamentally, the thing is sound. The economical factor comes into it again—but we have not yet learned how to bring the cost down of all the devices to make it highly competitive with the existing driven exciter. There are certain cases where this does not apply; for instance, where the power factor must be kept constant with varying load. We have to do more work on the technique of design and manufacture in order to get them really competitive for this equipment.

J. W. Murphy: Does the characteristics of the tube change appreciably throughout its life?

W. C. White: There is a certain small change. A marked change usually indicates that the tube is nearing end of life. The way they do in automatic train control work is to take the tubes out once a month, at a time when the engine is in the roundhouse for inspection or overhauling, and conduct a brief test on them. In doing this, they catch tubes before they fail.

J. H. Wagner: Mr. White talks about the life of the tubes—is that in hours or years?

W. C. White: A year at 24 hours a day—that is—about 8,000 hours.

G. E. Adams: I would like to ask Mr. White whether the Thyratron tube has the necessary characteristics, such as speed and reliability, to make it applicable for regulator service. I am referring to high speed sensitive regulators where a very high degree of accuracy is required.

W. C. White: The opportunity for regulators on alternators is the most available field. The most promising way is to combine the regulator with the exciter. By that I mean to use a rectifier for exciting the field and applying the regulator principle to the grid of the rectifier tubes so as to combine the function of regulator and exciter in one unit. Regulators have, of themselves, gotten to such a high degree of development that I doubt whether we get a lot out of substituting one regulator for another, except when it is a question of whether the tube regulator can allow you to do the job in a different way or many times as quick as the present one. In Thyratron tubes, it takes only a voltage impulse about 10 micro-seconds long to trip them.

O. P. Robinson: I would like to ask what the Pliotron tube is and what it is used for, and what is the difference between that and the Thyratron?

W. C. White: These are General Electric names. We have the Kenotron family of tubes which consists

of those of the high vacuum type. The prefix originated from the Greek root signifying nothing—in this case a high vacuum. It is used in connection with high vacuum tubes as a generic term. "Tron" is simply a suffix signifying a device or a thing. Phanotron is also a generic term that is used. That is the term for a gas or vapor content tube and signifies a glow or luminous haze. The Thyratron is the three-element member of the Phanotron family. The Pliotron is the three-element member of the high vacuum or Kenotron group.

O. P. Robinson: The 100 ampere tube—is that amount of current available or is that the current used to make the tube operate?

W. C. White: That is the average current that goes through the tube. It is a half-wave type and 100 amperes is the average current that passes during the whole cycle so that it is 100 amperes as measured on a D.C. meter in the anode circuit. The peak current rating is something like six times the average current.

J. W. Murphy: You failed to bring out the fact that the negative half-wave of the alternating current can also be utilized by the use of a second tube.

W. C. White: Of those I have shown, all are of the single end design. These units are half-wave devices. By properly connecting two tubes in combination, both halves of the wave can be rectified.

E. C. Marshall: Are gases used in addition to the vacuum tube and the mercury vapor tube?

W. C. White: I mentioned vapors or gases. The same principles apply to any gases which are inert in regard to chemical action to the cathode and which in the tube give reasonably low voltage drops. For argon and neon, there are certain advantages and disadvantages. The voltage drop is higher in those gases but they are freer from certain temperature effects.

J. M. Zimmerman: Does the mercury become effected by the high temperature? Are you able to shut off the control in a room at 110°F.?

W. C. White: It is necessary to keep the temperature in a certain range, and this is an important factor in mercury tubes. In extreme cases of temperature variation, it is better to use the inert gas type of tube. The life, however, has a tendency to be shorter for the gas tube. Conditions determine the best form of tube to use. A temperature of 110°F. is not of itself harmful except as it represents one extreme under which the circuit must function.

H. D. Sanborn: In the diagram you have shown, there is an internal drop of say 10, 12 or 15 volts in the tube so that if the current is 10 amperes the voltage which is applied in that circuit is all available for the load except the amount lost in the tube drop. How high may the voltage go?

W. C. White: The best example is radio in transmitting stations. There is very little industrial use for 10 K.V. to 20 K.V. D.C. except in a very few special cases. In large broadcasting stations, however, the mercury type of rectifier tube is used. In radio station WENR, the D.C. voltage is about 18,000. The rectifiers give about 10 amperes at 18,000 volts. They are rated at 20,000 volts so that these tubes give you a splendid way of obtaining high voltage direct current.

We have built a number of equipments of that sort using the mercury type of tube. If you get much above 20,000 or 25,000 volts, then temperature regulation is required.

A Member: What is the approximate ratio between the magnitude of the controlling voltage and the controlled voltage, the controlling current and the controlled current?

W. C. White: That is again a matter of tube design. The extent to which the grid shields the filament or cathode governs that. In many cases, we have two types. One is called positive control and the other negative. In the latter, it is necessary to keep a negative voltage on the grid to prevent starting of the current. In the other, it is necessary to keep a positive voltage on the grid to make it start. As far as the grid current is concerned, the current required when the grid is negative is very small. In general, grid currents to control starting are of the order of micro-amperes.

A Member: The ratio of the control voltage?

W. C. White: It can be made any amount you want. In the positive type of tube, it is about 100 to 1. On a negative type of tube, it is somewhere around 15 or 20 to 1. This factor is subject to design and you may want it one way or other, depending upon different factors or conditions. Technically, however, a ratio is not the correct way of expressing this relation.

W. J. Rannells: It seems that in steel mill applications, at least at our plant, the most important present use of the vacuum tube is the use of the photo-electric cell and we have two different installations practically the same, one is a Westinghouse outfit and the other a General Electric. The photo-electric tube proper of the General Electric is a high-vacuum tube and the Westinghouse is a gas-filled tube. I want to ask, in the photo-electric tube, what are the advantages of one over the other?

W. C. White: Up until January 1, 1930, all of the vacuum tube manufacture for the Radio Corporation of America was jointly done by the Westinghouse and General Electric Companies. The first application of photo-electric tubes was in connection with talking pictures. As in the case of all RCA equipments, they co-ordinated their efforts. When the RCA organization split up in 1930, a large part of the radio tube manufacturing went to them but General Electric and Westinghouse continued in many cases to make the same types, each for their own work. Therefore, the present photo-electric tubes of the two companies are practically identical in appearance and general design and each makes a gas-filled and a high-vacuum type. It is a question of engineering of the circuit layouts and not of one being better than the other. The gas tube gives more current than the high-vacuum type. However, there is apt to be considerably more variation between the gas-filled tubes than between high-vacuum tubes. It is entirely related to the type of circuit

used with the tubes. It cannot be simply said that one type is better.

W. J. Rannells: Do both companies use the same type of material?

W. C. White: So far as I know. They look the same and the characteristics are about the same. Both companies make both designs of tubes and there is just a difference of choice between the two. The nature of the application has the most to do with it.

F. A. Wiley: Can the photo-electric tube be used for the control of street or yard lighting systems, lighting at a certain intensity of natural light and extinguishing them again in the morning at a certain light intensity, eliminating the human element altogether?

W. C. White: That is being done more and more. The application of that scheme is quite old. So far it has been done more in Germany than in this country. It is really probably as important to keep illumination constant in certain places as it is temperature. It is largely a question of proper application.

H. G. Hague: Is there a critical temperature for these photo-electric tubes—a fixed temperature not to exceed 110°F.?

W. C. White: There are no corresponding temperature limitations for the high-vacuum or gas-filled photo-electric tubes as is the case for mercury-filled types of control tubes where the control factor changes slightly with temperature. In case of temperature extremes, they can be put into an enclosure having two degrees of control. Photo-electric tubes can be operated at a temperature as high as 150°F.

H. G. Hague: That is what I had in mind.

W. C. White: In a mercury vapor tube, it is not the high temperature that is bad. The tube, in general, will operate well at 110°F. It is, in most cases, a matter of change of characteristic affecting the operation of the tube in the particular circuit rather than actual failure of the tube itself to function.

H. G. Hague: Would it be necessary then to frequently measure or calibrate the efficiency of that tube?

W. C. White: No. You do not have to. It depends upon the extremes you have to face in any particular installation and provisions made for these extremes.

R. O. Herbig: Will you give us some example of using vacuum tubes for the field control of the D.C. motor? Such applications have been made in wire drawing where they maintain a constant tension.

W. C. White: The wire, the tension of which is to be kept constant, can be passed through a light idler pulley on which hangs a small light cylinder of iron acting as a movable core in an inductance.

This inductance is included in the Thyratron grid circuit so that when its value of inductance is changed the phase of the grid voltage changes, which varies the motor field current.

Therefore, if the tension of the wire tends to increase, the core on the little inductance is moved and this varies the phase of the grid current of the tubes so as to result in more field current for the motor.

For details see paper by W. R. King entitled "Electron Tubes in Industry."

W. A. Ballenger: Another possible application for Thyratron tubes is in connection with heavy duty blooming or slabbing mill auxiliary drives such as the screw down and the side guards, which, incidentally, require exceedingly frequent and rapid operation. By the use of a motor generator set with Ward Leonard Control the conventional large capacity magnetic contactors, with their subsequent high maintenance, may be eliminated from the armature circuit, and Thyratron tubes may be employed in the generator field circuit to control direction of rotation and speed of the screw down motors.

W. C. White: That principle can be used to get quick response for changes in excitation in motors.

E. C. Marshall: We thank you for the excellent talk you have given us this evening. The way you answered these various questions and delivered your paper has certainly been enlightening. I feel greatly indebted to you.

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Electron Tubes In The Steel Industry

By L. F. WORDEN
Application Engineer, General Electric Co., Pittsburgh, Pa.

Presented before Association of Iron and Steel Electrical Engineers, Pittsburgh District Section, Oct. 24, 1931.

Electron tubes have been in everyday use in radio for a number of years, but only recently have they been extended to the problems of industry. The demands of automatic operation of motors driving machinery in the steel mills and allied industries offer many complex problems to the steel mill electrical engineer. New and definite solutions to these problems in the future are going to find electron tubes very much in the fore. They cannot be considered a panacea for these problems, but electrically and economically speaking they will have a lot to say.

Photo Electric Tubes:

The photo electric tube is a valuable tool because of its property of being able to perform electrical operations based on its sensitivity to light.

Two unique applications of this tube at present will illustrate the point. It is being used in the Holland Tunnels connecting New Jersey with Greater New York to count the number of vehicles passing through the tunnel. Another entirely different function is utilized in a beansorting machine. Here the amount of light reflected from the beam to the eye is employed to eliminate stones and dark beans from the product.

The photo electric tube is a two element light sensitive device depending for its operation on the flow of current set up by the action of light on a specially coated electrode. This property can by proper amplification tubes and relays be used to control other operations electrically.

Advantage of the property described above can be secured in several ways; by allowing an opaque object to shut off the light supplied to the tube from a definite light source; by change in the amount of light reflected on the photo electric tube; by direct light emitted from the object itself.

The functions of the photo electric unit can be used to control auxiliary motions electrically or to record or count the objects passing through the beam of light.

The photo electric unit can be used in steel mills in nearly any department. The following are some actual and suggested applications. No doubt any group of steel mill men could think of many more, but these few are offered as typical examples.

In the Blast Furnace and Open Hearth Departments tubes have been applied to ore and other material bins to control the level to which these bins are automatically filled. This can be done readily with a direct light source focused on the "eye" which when cut off by the material closes the feeder gate. A similar application can readily be made to automatic scales for weighing material. A small disk carried by the pointer of the scale used to cut off the light would eliminate delicate, exceedingly low voltage contacts often used on automatic scales. Photo electric relays have been used as position indicators for skip hoist buckets and also for spotting moulds for pouring in iron foundries.

Another very definite and useful field to which the photo electric tube has been applied is that of a radiation pyrometer. Our company has had several in operation over a period of months on tungsten furnaces. The "eye" is used to control the temperature of these furnaces to within +or—10°C. These units have an advantage over thermocouple pyrometers in that they eliminate an inherent delay in these latter devices. Radiation photo-electric pyrometers can be supplied which will eliminate errors due to voltage and frequency fluctuations. They must be calibrated about once a month with an optical pyrometer.

Photo-electric relays have also been applied to water purification plants in connection with the filter system. It is possible that this application can be used in the mills.

In the Blooming Mill departments, application of the photo-electric relay to soaking pit installations is of interest. In this case soaking pit covers are opened and closed from the crane cab by simply flashing a light source on the eye of the tube. A second flash of the light closes the pit cover. By properly arranging the right number of photo-electric tubes a seven rail sectionalized trolley scheme was eliminated. This installation ought to pay for its self in rails and shoes if no other way. Here again it appears that the radiation pyrometer described earliest might be very useful. In addition, there must be some field for the photo electric tube as a limit switch for automatic operation of ingot transfer equipment.

In the Blooming Mill Rolling equipment photo-electrics have been used as a limit switch.

Going from Blooming Mill department into the semi-finishing department, like the Billet, Bar, and Merchant Mills, we find applications for the photo-electric relay as a limit switch. In many cases, the direct light of the steel can be utilized to operate the relay. The speed and weight of the material traveling in tables in these mills makes the use of mechanical flags expensive from an upkeep standpoint.

In these departments, photo-electric tubes have been applied to shears and for kick off operation to the cooling bed after shearing. The photo-electric relay operates at high speed and once adjusted should offer better accuracy of cut in shear operations. The photo-electric eye itself being a compact unit separated from amplifying tube and relays can be easily mounted on guides above or below the table. This feature should offer a better solution to the problem of cutting different lengths on the shear table. This application has already been tried out and is in successful operation.

Probably most applications for photo-electric tubes will be in the finishing departments in the pipe and tube mills, roll, tin, and continuous strip mills. The use of the photo-electric relays on a con-

tinuous reheating furnace has proven successful where on previous installations difficulty was encountered because mechanical flags would not withstand the heat. In this case, the material on the conveyor inside the furnace cuts off light focused across the inside of the furnace with photo-electric tube mounted on the opposite side, outside of the furnace. In another case the photo-electric tube replaced a limit switch which due to light weight of material gave faulty operation to an automatic conveyor in a continuous furnace.

In the mill proper the photo-electric has been operated from light emitted by the steel itself to control the scale spray valves. Here again due to the impact of the material at high speed the mechanical flag switch did not do a 100% job. Two applications of this type are now in operation.

On continuous mills of all types the present day practice in between stand looper operation is to use a low voltage relay which can be operated from the drop across the commutating field of the driving motors. It is felt that photo-electric relays would prove a simpler device to do this job.

The use of the photo-electric pyrometer should find application in hot finishing departments and in welded tube mills use could be made of the photo-electric eye to control the temperature of the weld. This scheme is now in operation on link welding machine in a chain manufacturer's plant.

Recent developments in the sheet and tin plate mills have seen machines applied to these mills for automatically handling the material during the rolling process. The rapid and severe service which these machines have, subject a flag switch to very severe service.

One plant is now replacing this limit switch with a photo-electric relay.

Pliotron Tubes:

No discussion of electronic tubes would be fair unless some time was devoted to the Pliotron tube. First because of its necessity on many applications and also because it was perhaps the first electron tube to establish itself in industry.

Some of the most important applications of this tube is in automatic levelling control in high speed elevator work and in automatic train control on the railroads.

The pliotron tube is a three element high vacuum tube with a plate, hot filament and grid circuit. The pliotron tube is a rectifying tube in that if an A.C. voltage is applied to anode and filament and the filament heated, the tube will pass half wave pulsating direct current. By applying the proper bias to the grid of this tube the grid can be used to control the flow of plate current. Under these conditions there is a definite relation between grid voltage and plate current. Since the grid circuit of the tube requires small amounts of power the tube is used in the standard photo-electric unit to amplify the very low current changes recorded by the photo-electric or light sensitive tube. This principle is also made use of in train control work where the weak track currents are picked up in the grid circuit and amplified sufficiently through the plate circuit to operate signal relays. By inductively coupling the grid circuit of a pliotron tube to its plate circuit, oscillations may be generated. This principle is used in the levelling control on elevators. The cars are equipped with iron vanes which when carried in this oscillating circuit causes the oscillations to cease; at this point a relay is closed which starts the levelling operation.

Application of these tubes in the steel industry will probably be chiefly as an amplifier of small currents.

Thyratron Tubes:

The third and last tube to be considered is perhaps the most interesting and has not been so widely applied in the steel industry as yet. This tube will be heard from more and more as time goes on. One of its best applications to date is in the lighting field for theater work and outdoor sign operation. Interesting installations at present are the stage lighting in the new Earl Carrol Theater in New York and the Chicago Civic Opera House.

Fundamentally the Thyratron tube is a mercury arc rectifier incorporating a control electrode or grid circuit. In a Thyratron tube, for a given plate voltage there is a particular grid voltage at which ionization will just occur and allow the tube to pass current. With the grid voltage above this critical value the tube continues to pass current so long as the anode of the tube remains positive as compared to the cathode. Control of the grid circuit can be secured by either a change in its voltage or by a method of phase shifting the grid voltage relative to the plate voltage.

By proper control of the grid voltage on the Thyratron tube, it can be made to act as a valve, i.e., delay the flow of current through a tube. For this reason the Thyratron tube is used to supply to D.C. power to solenoids, contactor, coils, magnetic clutches, and brakes. The use of the Thyratron tube offers a definite high speed control of the coils on these devices through the medium of the lower current grid circuit. There are no contacts involved. By this scheme the small current change of a photo-electric cell can be utilized to operate a contactor coil without requiring contacts.

The simplest form of the Thyratron tube as a controlled rectifier is the single phase, full wave, grid controlled rectifier. By properly controlling the grid circuit of the two Thyratron tubes used in this hook-up some interesting problems have been solved. The chief feature of the scheme is that the D.C. output voltage can be varied throughout its range smoothly and without steps.

Some applications already made of the Thyratron tube will illustrate its usefulness. High speed resistance spot welders are now in operation in which it is unnecessary to use a heavy current mechanical contactor to break the current. In this scheme which applies to the A.C. spot welder a series transformer is connected in the welding transformer circuit. By saturating the core of this transformer with D.C. power derived from Thyratron tubes the power delivered to the welding transformer can be cut-off or allowed to flow intermittently at very high speeds. The control of the Thyratron tubes is through the low current grid circuits in which small high speed mechanical interrupters can be successfully applied.

This same idea of a saturated core series transformer is applied to the theater dimmer, except that in this case control of the grid circuits is through a

Selsyn which is used to control the phase displacement between the plate and grid voltages and in this manner control the critical voltage which the Thyratron tubes start to pass current. Likewise the magnitude of the D.C. voltage applied to the core of the series transformer can be controlled. The Selsyn system offers the additional advantage in this set up that lighting effects desired can be pre-set on the transmitting Selsyn at a distant point. By properly laying out the required light circuits and colors some very effective and inexpensive stage or other decorative lighting can be secured.

In the reeling of very fine copper wire Thyratron tube control has solved a real problem. The small tension required for rewinding this fine wire after it has been drawn through the last die precludes the use of constant current regulators or other forms of tension regulation, such as is at the present time applied to cold strip mills. In the past, slip clutches were used to maintain a practically constant tension in the reel as the diameter of the reel increases and as the linear speed of the wire varies. By drawing the wire over a movable pulley which in turn moved a plunger in and out of a solenoid and using the change in the reactance of the solenoid in the grid circuit of two Thyratron tubes operating as a single phase full wave rectifier this problem was solved. The output voltage of the Thyratron tubes was used to control the armature voltage of a 1-HP motor driving the rewind drum.

This same principle has been used to supply the field voltage to a 5-Hp adjustable speed motor driving a reel which is rewinding continuous strip coming from a pickling and scrubbing process. Tension is maintained again by allowing the strip to ride over a movable roll which operates a plunger in and out of a standard solenoid.

Maintaining the water level in a tank to very close levels by means of a float which controls the position of the plunger in the solenoid, and the grid controlled Thyratrons supplying power to the field of an adjustable speed D.C. motor have replaced a multi-point commutator type field rheostat previously used on this application.

Discussion

▲

Question—What is the life of the tubes?

T. R. Rhea: Manufacturers will not make guarantees on the life of tubes. But for light relay duty, such as the automatic screw down application, the life should be between 5,000 and 10,000 hours.

Question: Will you explain how accuracy is obtained when using two Selsyns geared together?

T. R. Rhea: Accuracy is obtained by using two Selsyns geared together, one coarse and one a vernier. The coarse Selsyn brings the screw down motor into approximate correspondence and the vernier Selsyn takes up the job where the coarse leaves off and brings it into exact correspondence.

H. L. Wilcox: With regard to automatic screwdown control, I would like an explanation of the action between the Selsyns and the Thyratron tubes. In other words, how does the angular displacements of the Selsyns set up the voltage wave which controls the grids of the Thyratrons?

T. R. Rhea: One Selsyn is connected to the screw down motor, and another Selsyn, on the preset panel, excites it. The voltage from the secondary of the Selsyn on the screw down motor is proportional to the angular displacement between the preset Selsyn and the Selsyn attached to the motor. The output voltage from this Selsyn is applied to the grids of thyratrons. When this voltage is high enough, that is when the angular displacement is great enough, the thyratron conducts. The thyratron is simply used as a relay and about 5 degrees displacement between the Selsyns is sufficient to cause the thyratron to conduct.

H. L. Wilcox: I would like to check my understanding of the Selsyn Thyratron control. I understand that the sending Selsyns are located in the pilot house and the receiving Selsyns are geared to the screwdown motor. When ever an electrical displacement between the sending and receiving Selsyns occurs, such as when a new setting is made, a voltage is generated which, when applied to the grid of the corresponding Thyratron, causes it to pass current, to operate the proper contactors, to drive the screwdown motor in a direction to decrease the displacement. When the screwdown motor revolves sufficient to bring the receiving Selsyn in exact phase with the sending Selsyn the generated voltage disappears and the Thyratron action ceases thereby stopping the motor.

T. R. Rhea: Your understanding is correct.

H. L. Wilcox: One question in regard to welders. It was brought out that, by using Thyratrons in connection with a series transformer connected in series with the welding current, the large capacity contactors necessary for interrupting the welding current might be eliminated. What are the connections for such an arrangement?

T. R. Rhea: Let us take the welding transformer with its heavy secondary of a few turns carrying the welding electrode. In series with the high voltage primary we will place this series transformer. When the secondary of this series transformer is open, it provides a high reactance in the welding transformer circuit and prevents the passage of current. When the secondary of the series transformer is short circuited, it allows the passage of current to the welding transformer. The problem is to obtain some form of contactors that will provide the short circuiting of the secondary of the series transformer in exact synchronism with the alternating voltage. Thyratrons are used for the service of short circuiting the secondary of the series transformer and their grids controlled by a synchronous timing device. This means the welding transformer will be permitted to pass, say, 5 cycles of current, skip 5 and pass the next 5. The Thyratron system with the synchronous timing of the grids does this exactly and does not get 5¼ cycles one time and 6 the next and 4 the next. Thus, just exactly the right amount of energy is put into each impulse of the weld. Another feature of the Thyratrons is that they replace contactors which could not stand the frequent service. It does not matter how frequently

you operate a Thyratron, as there are no mechanical parts to wear out.

C. F. Barry: In the vacuum tube you can vary the cycle of the current so it will operate a motor at a different speed?

T. R. Rhea: You can make a frequency changer with Thyratrons, but I doubt if it is commercially feasible, as yet, for power work. It is still a research problem.

C. F. Barry: Could you get a range of 50 cycles to 150?

T. R. Rhea: No limit.

C. F. Barry: What is the maximum of power you can raise through these tubes?

T. R. Rhea: The mercury arc rectifier is just a large polyphase thyratron without the grid control features, and can be obtained up to 3,000 volts and 3,000 kilowatts D.C. They are quite successful now on railroads.

J. Houssman: On the flying shear installation, mentioned earlier, was any provision made to stop the shear from cutting off the tail end of the bar, or snapping idly when the last piece is short?

T. R. Rhea: I am not familiar with the problem to which you refer, but I dare say we can solve it if we put enough gadgets on it.

L. F. Worden: We have available a complete photo-electric equipment operating a thrustor here at the meeting. If you want to see it operate we would be glad to demonstrate it to you. By directing the light beam on the photo-electric eye the thrustor motor is de-energized.

D. W. Dean: I certainly want Mr. Worden to know that I really appreciated his talk tonight, particularly since I am scheduled to give a talk on the same subject October 31, before the Philadelphia Section of the Association of Iron & Steel Electrical Engineers.

In my discussions with numerous operating engineers in the steel industry, the question has frequently been raised as to the practicability of electron tube devices from the standpoint of mechanical ruggedness. Certainly, the discussion here tonight has indicated that the electron tube art has now reached the point that tubes can be applied in industry with full confidence in their mechanical ruggedness to do the job for which they are recommended.

The question as to the economics of the tube application will have to be decided for each individual case through the co-operation of the manufacturer's representative and the steel mill engineer. Most assuredly this phase of the subject should be closely watched and the progress of electron tube applications should not be retarded by making applications that are not economically justified.

As indicated by the discussion, the photo-electric cell will undoubtedly find its most practical field for steel mill applications in its use as a flag switch device.

I believe that one of the most important developments in the immediate future will be the rapid increase in the use of grid-glow tubes, or as they have been called here tonight thyratron tubes, in motor control applications. The grid-glow tube can be conveniently used in many applications for armature control of the small direct current motors from an A.C. source. I have in mind one such application where the operator of a coil winding machine can obtain any speed from a few RPM up to the maximum desired on the coil spool by merely pressing a small foot treadle which controls the output of grid-glow tubes. This coil winding machine is driven by a 1-HP, 230 volt adjustable speed direct current motor from an A.C. source, and the rheostat is used only to preset the maximum desired speed. Undoubtedly, the use of the grid-glow tube for motor control represents a fertile field for steel mill applications.

J. Farrington: I would like to ask if any gentlemen present have had any experience on length of life of tubes based on 2,000 operations in an hour, or how long the tube will last at that frequency of operation; also if the intensity of light has any bearing on the speed of operation? In other words, can you get as fast speed with small light directed into the eye as with a volume of light?

T. R. Rhea: There is no practical limit to the frequency of operation of the Thyratron as a relay. It will operate satisfactory at 500 cycles or at 10 cycles. There is no appreciable time delay in the Thyratron. The photo tube could very easily operate 2,000 times an hour without difficult and it does not have a time lag. The relay or contactor that the Thyratron or photo-electric tube controls would probably be the limiting feature of a number of operations per hour.

J. Farrington: What is the relative intensity of light?

T. R. Rhea: The current passed by a photo-electric tube is of the order of micro-amperes, 15 or 20. There is no time lag in the photo-electric tube. You apply so much light to the photo-electric tube and it immediately passes so many micro-amperes. You remove the light and the current immediately drops down to the so-called "dark" current power, possibly 1 or 2 micro-amperes.

J. Farrington: You have a certain heat from the light that operates your cell and as long as you have sufficient heat to operate the cell is any in addition wasted?

T. R. Rhea: As far as the photo-electric tube itself is concerned, the amount of light would make no difference. If we took the telephone relay and pliotron out of the system and used a thyratron instead, any light in excess of that necessary to trip the thyratron would not be necessary and would be wasted.

J. Farrington: In experimenting with the photo relay we began operating with the light of a 50 watt lamp. We seemed to get the same frequency of operation (2,000 an hour) with the 25 watt lamp as with the 50 watt lamp.

T. R. Rhea: The time delay was probably due to a relay somewhere in the system. If you use a photo-electric tube, a pliotron which in turn operates a relay, the amount of light impressed on the photo-electric tube will make a difference in the

speed of operation of the relay supplied from the pliotron, since in this case the system will supply a current signal to the magnetic relay proportional to the amount of light on the photo-tube. The more current you apply to the magnetic relay, of course the faster is its operation. The speed of operation of the photo-electric tube as a relay can easily be made independent of the amount of light used if a thyratron is used instead of a pliotron.

J. T. Nichols: We have had some experience along that line. We are using a unit similar to this one to count sheets at the rate of 120 a minute. We do not know how long it will last, because we have only had it six months; that accounts for several thousand hours operation at 10 hours a day. As the intensity of light, increases the current output increases in proportion. When you have enough current to operate this relay you have all you need and you can't change the response by increasing it. With a unit like this, if you want to be sure to have it work you want a 50 watt light at 3 or 4 feet or a smaller lamp with reflector to increase light intensity on the cell itself.

A. C. Cummins: Judging by what has been said at this meeting, light sensitive cells and also pliotrons and thyratrons are destined to introduce radical changes in the methods of controlling the processing of material in the steel industry. It does not follow, however, that these devices will be universally applied without difficulty. Conditions in the steel industry, particularly in that section which is devoted to the rolling of steel, are in no way comparable to that of the laboratory and for this reason it will, in a sense, be necessary to transfer the laboratory to the mills. The effect of various thicknesses of scale on heated material which in turn varies the amount of light radiated by different pieces has to be taken into consideration, as well as the effect of clouds of steam and dust which are prevalent in the vicinity of rolling machinery. There is no question that these factors will ultimately be overcome, although at the present time they have caused disappointments in the application of light sensitive cells.

One factor that is becoming more generally recognized as being of great importance in the making of higher grade steels is the necessity of having each piece rolled under duplicate conditions. With manipulation under the control of the average workman, there is a wide divergence of rolling practice and temperatures.

Light sensitive cells or other devices which ultimately will assure absolute uniformity in the treatment of successive ingots from the time they enter the Blooming Mill until they leave the finishing stands will do much to help quality and will make it very much less difficult to determine the causes of defects in the finished product.

The apparatus that has been described this evening can be considered as in its infancy as far as its application to the steel industry is concerned. The discussion has reminded me of the discussions which were held many years ago under the auspices of this Association as various improvements in accelerating devices for magnetic controllers were introduced from time to time.

One of the obstacles in applying light sensitive cell apparatus now on the market is the limitation of the length of the leads which are permissible between the light sensitive cell and the amplifying devices. With 60 cycle A.C. supply, 4 to 5 ft. is the maximum distance between the light sensitive cell and the amplifying equipment. This can be greatly extended by the use of D.C., but has the disadvantage of requiring a small motor generator set or rectifier, or some other device to supply a source of D.C. which is independent of the mill supply and not subject to changing ground conditions which occur on mill D.C. feeders. The D.C. equipment has been found in some installations to be delicate and require frequent adjustment. However, it is my opinion that all of these difficulties will be overcome in the very near future and there need be no fear of applying a light sensitive device to any control problem where either uninterrupted light or radiated light can be applied to initiate the control function. It might be that apparatus is now being developed by the electric companies which will overcome all the difficulties in the details of application that have been mentioned, and if so, it would be interesting to hear what the immediate future has to offer.

G. Baumgarten: We have just finished installing an ardometer ahead of the bloom shear in our 38 inch mill for measuring the temperature of the bloom in order to check the efficiency of the heaters at the soaking pits. To operate this device a single electrical contact had to be made while the steel was being sheared and the temperature recorded.

A small roller was first tried which was depressed by the bloom. This roller was subjected to considerable punishment due to the fact that occasionally the rotation of the table roller was reversed. Further trouble was encountered due to the fact that the table was not level throughout its whole length which caused a fluttering of the contact after the front end of the bloom had passed the switch.

Hot cobbles were also brought back from the mill and dropped on this table which damaged our roller. After a trial of a few weeks, we decided that this apparatus was not satisfactory.

Our next apparatus consisted of a photo-cell which was assembled from some experimental equipment. The apparatus was A.C. operated and the transformer amplifier telephone relay and an auxiliary relay were mounted in a steel box on a building column approximately thirty feet from the photo-cell. This was done in order that the minimum amount of this sensitive apparatus would be subjected to steel mill abuse, but this arrangement required two leads between the photo-cell and the amplifier which were approximately thirty feet long. Using a tirex rubber cable it was found that without the photo-cell in the socket sufficient capacity current was obtained to operate the relay. In an effort to eliminate this capacity current an armored cable was tried and the armor was grounded.

This scheme seemed to be satisfactory except that after an hour of mill operation the grid circuit of the amplifier was unbalanced which necessitated an adjustment of the potentiometer in the grid circuit. The adjusting of the grid potentiometer was objectionable, therefore, a grid-glow amplifier with

a relay which was adjustable as to drop-out and pick-up values, was tried.

In this case we found that even after grounding the sheath of our armored leads that ten milliamps. of capacity current remained whereas the relay we were using had a maximum adjustment of but four milli-amps.

From these experiences it was apparent that D.C. operation of the photo-cell was required in order to eliminate the troubles due to capacity currents. It was found that D.C. operation of the photo-cell was not wholly satisfactory when using a mill D.C. supply due to the fact that there were floating grounds first on one side of the line and then on the other. Therefore, some sort of rectifying equipment must be used with the photo-cell.

All of these troubles convinced us that the ardometer was not an ideal application for a photo-cell equipment. Therefore, we have developed and are now using an air-vane which controls a mercoid switch.

We have also done some experimental work with photo-electric equipment in an effort to make fully automatic an ingot turning device and an auxiliary table. We found that the heat of the ingots affected the grid circuit of the amplifier tube if the apparatus was located too close to the ingot. The light source was not a highly concentrated beam at that time and frequently a very hot ingot with very little scale on it would pass through the beam of light without operating the photo-electric relay. It was found that the light of the ingot was not satisfactory as a tripping medium because variations in the amount and thickness of the scale on the ingots would cause faulty operation of the control relay.

Our conclusions from the above experiments are that a D.C. operated photo-electric equipment, using rectifiers; a highly concentrated light beam and a screen before the light sensative cell with a small opening on which the light source is focused, are required for satisfactory operation on this application.

T. R. Rhea: Whenever you have a photo-electric tube application and it is necessary to put the photo-electric tube a considerable distance from the amplifier tube, you should use D.C. on the photo tube instead of A.C. When D.C. is used the trouble due to capacity currents are eliminated. We ran into these difficulties when experimenting with pyrometers. It is necessary to put D.C. on the photo tubes and it must be at a constant voltage also.

G. R. Carroll: In a location where D.C. power is available and it was desired to operate 60 cycle equipment in this location, how big a 60 cycle motor would be practical to run from the direct current power using the thyratrons as inverted rectifiers?

T. R. Rhea: The thyratron on the panel before you can carry an average D.C. current of 5 amperes per pair. The next larger size will carry 25 amperes D.C. per pair. The maximum voltage is around 1000 volts. At the present time that is about all that is commercially feasible. The larger sizes are still somewhat in the research stage, but are coming along fast. The larger sizes come between the mercury arc rectifier and the small tubes.

R. Leech: I notice C. D. Rowell, Electrical Engineer for the West Leechburg Steel Company, in the audience.

Mr. Rowell has had considerable experience in the application of a light sensitive cell to the operation of a repeater on their hot strip mill. He has had a particular problem involving high temperatures and, if he is willing to discuss them now, I am sure they will interest all of us.

C. D. Rowell: We have a photo-electric cell application at our plant that will possibly be of interest to some of you. It was with some apprehension that we undertook this installation, but, now do not regret having done so.

In transferring hot strip steel from the roughing to the finishing side we use what we call a "Repeater". This repeater consists of two circular gates that are normally closed. As the strip passes around the inside of the circular gates and enters the finishing mill they are automatically opened to allow the loop to accumulate or build up. When the tail end of strip leaves the roughing pass and the loop has straightened out the gates are closed. A 12 H.P. motor operates the gates.

We originally had dogs connected mechanically to two limit switches which handled the control circuit of the gate motor starter. The impact of the strip against these dogs broke them, and by making the dogs stronger, the end of hot strip would double over and consequently would not enter the finishing pass following the repeater. We endured this trouble for more than a year, being unable to rig up a device that would do the work satisfactory.

We became interested in the light relay so much that we purchased a Westinghouse Type "C" relay and a few auxiliary contactors without getting the manufacturer's recommendation or advice as to the feasibility of its use on our repeater.

The source of light or light unit was placed inside circular gates, and the cell unit was located about fifteen feet away and out of danger of being damaged. The strip steel passing on edge through the repeater intercepts the beam of light falling on the light relay and causes it to pass current. We use this current to start our control panel to operate which opens the gates, and hold them open as long as the beam of light is being intercepted. As soon as tail end of strip passes the beam of light the gates close, ready for the next strip. This cycle is repeated two or three times every minute.

We of course had our misgivings. We did not think the light from the hot strip (about 1900°) would operate the photo-electric cell. This it did not do when it was fifteen feet away, but as the loop built up and was brought within a few feet of the relay it functioned and started to close the gates. Presence of mind on the part of one of our men saved the first strip. This man grabbed his hat and placed it in front of the opening where light entered the light unit. This man and his hat was kept busy the remainder of the turn.

In the meantime we did some original experimenting. We realized that the photo cell was too sensitive. We tried several methods of reducing its sensitiveness and finally had the thing licked. We wrapped a piece of dark grey fish paper around the photo-electric cell. At the exact focal point of lense that collected the beam of light we cut a round hole, about $\frac{1}{8}$" diameter, in the fish paper. The only

light that reached the cell was through this 1/8" hole.

Our troubles were then over, and this outfit has now been in operation more than eleven months. It has given no more trouble, and requires no more maintenance than any piece of electrical apparatus. There has been only one tube renewed during the eleven months of service.

If any of you men should desire to see our outfit operate, I would be glad to show it to you.

J. W. Bates: We have had several applications of photo-electric cells; Mr. Nichols described one using the cell as a counter on a slitting shear. As the other applications are in process of development it would be premature to discuss them now.

I would like to ask Mr. Rhea one question about the thyratron. It is my understanding that the device can be inverted so that D.C. is fed into it and A.C., of any predetermined frequency, secured on the other side. As such a use would present interesting possibilities I would like to hear more about it.

T. R. Rhea: The theory of the inverter is a pretty involved one. You can feed direct current into an inverter and get out A.C. The frequency of the alternating current obtained can be controlled. You could change the A.C. which you received from the inverter back into D.C. at a higher voltage by the use of more thyratrons. Thus you would have a D.C. transformer.

J. T. Nichols: When making my former statement I did not wish to create the impression that the counting apparatus was the only thing we had along that line. We have some safety devices. I do not think the point was brought out that the photo cell can be used to shut off any apparatus. It can be applied to a shear, so that if a man puts his hand under the shear it can't be operated. We are successfully sorting sheets as to gage; so as to throw out sheets off gage more than the commercial tolerance, and we have other applications under development, which I am not in a position to talk about now.

H. L. Coe: Will you please explain the way in which the armature shunt and the brake are applied to the screw down motor previous to its stopping? It seems to me that you are likely to find stopping somewhat inaccurate when this scheme is applied to a large screw down motor, say 100 horsepower.

T. R. Rhea: The accuracy of stopping on large motors, such as 100 horsepower screw down motors will be quite as good as on the small model exhibited here. We are frequently faced with the accurate stopping problem on shear drives and the like and have no difficulty in meeting the requirements. The control contemplated allows the motor to rotate slowly when near the correct position and the brake can be depended upon to stop the large motor accurately and quickly.

Behavior of Photo-Electric Relay

By JAMES FARRINGTON
Superintendent, Electrical Department, Wheeling Steel Corporation, Steubenville, Ohio.

TEST #1—Using #14 R. C. solid wire twisted together tightly (various lengths) photo-relay will operate on eye opening of 3/16" x 1/2". By untwisting wires, relay will not operate on eye opening of 3/16" x 1/2" but will operate on an eye opening of 1/4" x 1/2".

TEST #2—Using #14 R. C. solid wire 35' long in 1/2" conduit, photo-relay will energize on an eye opening of 3/16" x 1/2" but requires three seconds to de-energize after light beam is shut off. Conduit grounded or ground removed, no change noticed.

NOTE:—Energize and de-energize is used in the same sense as operate.

TEST #3—Using two pieces of #14 R. C. solid wire (various lengths) laying side by side, relay can be adjusted to operate on an eye opening of 3/16" x 1/2" but when using lamp cord, three feet long, which is furnished with the relay, it is necessary to readjust the relay.

TEST #4—Using two pieces of #16 R. C. flexible wire, seven feet long, relay will operate on an eye opening of 3/16" x 1/2" but will not operate on an eye opening of 1/16" x 1/2". By taking the same leads and twisting them together the relay will operate on an eye opening of 1/16" x 1/2". By installing the same leads in flexible steel conduit the relay will not operate on an eye opening of 1/16" x 1/2" but will operate on an eye opening of 3/32" x 1/2".

Lubricating Steam Cylinders

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Credit is extended to Freedom Oil Company, Engineering Extension Bureau of Pennsylvania State College and Osborne's Power Plant Lubrication.

Although, when steam cylinders are mentioned, the steam engine is at once called to mind, there are many other uses of steam cylinders. Among these are the steam cylinders of pumps, air and refrigerator compressors, steam hammers, shears, presses and the various steam cylinder uses for moving carriages and tilting tables as in the saw mills and rolling mills, to mention a few of them. In all of them the same general conditions obtain and, therefore, the principles of lubrication outlined are adapted to all of them.

Cylinder Friction. A steam cylinder is lubricated to reduce wear of the cylinder wall, the piston and its rings, and to reduce the power losses caused by friction. In connection with cylinder lubrication, it is necessary also to lubricate the piston rod, the valves and the valve rods or stems.

Cylinder friction is a very large portion of the total frictional losses of an engine and sometimes eats up as much as 10 per cent of the coal pile. Some engines will run freely for many revolutions after the steam is cut off; others slow down as if a brake had been applied. The free-running engine can be made to slow down quickly if the cylinder oil is cut off for a time before shutting it down, showing very clearly that the braking effect is due to cylinder friction.

Indications of Poor Lubrication. It is easy to tell when a cylinder is not being lubricated properly, by the action of the engine when running, or by the length of time it will run after the steam is shut off. Every engineer knows, when he hears a groaning sound coming from the cylinder, that the piston or rings are not sliding freely over the cylinder wall. If he sees the valve rod vibrating excessively, or a Corliss valve fail to come back promptly after being tripped, he knows that at some point the valves are not getting proper lubrication. A listening device has been made to detect insufficient lubrication and even the exact place where the dry spot occurs.

Difficulty of Maintaining Film Lubrication. One cannot expect to secure within the cylinder the same sort of film lubrication that is maintained in cylindrical bearings. There does not seem to be any way of maintaining, on the cylinder wall, a film of oil thick enough to prevent all contact between the piston and rings and the wall.

A flood of oil cannot be supplied to the cylinder wall as is done with a circulatory system for bearings, because the quantity would be enormous and most of it would be carried out of the cylinder at every stroke and lost. Furthermore, if a thick film of oil were formed, the oil would drain off by gravity, owing to its low viscosity at the high temperatures encountered in steam cylinders. Piston rings cannot be made to slide on a wedge-shaped film of oil, because if they are beveled they will also leak steam.

Imperfect Film Lubrication. Lacking perfect film lubrication, the next best thing is to make the rubbing surfaces as smooth as possible and provide them with an oily coating that will reduce the friction during actual contact. If the oil contains suitable constituents, it will soak into the pores of the metal and a mirror-like glaze will be formed over the inside surface of the cylinder. A properly lubricated cylinder will have a bright surface as smooth as glass, free from any rough or porous spots. Pistons and rings will be in like condition. Friction will then be reduced to a minimum and the engine will run smoothly and quietly, free from noises and vibration caused by lack of sufficient and proper lubrication. This condition must be maintained under all kinds of adverse influences of temperature, pressures, moisture, alkaline water, sediment, piston speeds, and steam velocities.

Source of High Cylinder Polish. Sometimes, when changing from one kind of cylinder oil to another, upon examination after a few days' operation the engineer finds that the polish has gone entirely from the cylinder wall. A few days later it comes back again, indication that some kind of a compound different for each of the oils was formed on the surface of the metal. If, for some reason, the glaze is destroyed and is not quickly reformed, the cylinder will begin to wear, even though large quantities of oil are used. Every condition should be made as favorable as possible to the formation of a new film, and it always is a good plan when changing from one cylinder oil to another, to feed an excessive amount for a week or 10 days to assist in the formation of a new polish in case the old one has been dissolved by the new oil.

One theory of the way in which this glaze is formed is that the oil and the metal combine to make a new compound, which gives a smoother surface to the metal and reduces friction. Sometimes there is a glaze on the cylinder depending for its lubrication entirely upon the moisture in the steam. Here it cannot be said that the glaze is caused by the oil. The polish also is affected by many other things, such as moisture in the steam, alkalies, acids, and organic matter which may be brought into the cylinder with the steam from priming boilers. There is also the possibility of rust, scale, and other metallic substances getting into the cylinder when steam is first turned into an engine that has not been operated for some time.

Direct Oil Feed. There are many different mechanical designs of pistons, cylinders, valves, etc., and while some of them require special attention in many respects, there are only two basic methods of applying the lubricant. One plan consists of feeding the oil directly to the rubbing surfaces. Poppet-valve stems and Corliss valves are lubricated in this manner. Piston rods are sometimes lubricated by introducing the oil into the packing gland or by

feeding the oil directly onto the rod from a drip cup mounted on the top of the gland.

Atomization Method of Feeding Oil. Every part of a steam cylinder that requires lubrication is touched at least once in every revolution by the steam. This applies also to the greater portion of the valve surfaces. If the steam can be made to carry oil in suspension and deposit it on all these surfaces there exists the best possible means for providing lubrication. Even though it is not possible to produce a film of lubricant so thick that the metals cannot touch, yet, by a proper combination of oil and thorough atomization, enough oil can be kept on the surfaces to reduce friction and wear to a minimum.

Small Drops More Economical. A finely atomized oil will remain in suspension in the steam better than one divided into large drops. The surface in contact with the steam per unit of weight is greater, and there is not so great a tendency for the oil to be thrown out of the steam at the turns. An improperly atomized oil will collect in any pockets in the pipe-turns or in the valve chest, and will not be carried to the parts where it is needed. Such oil is wasted.

Regulation of Drop Size. The factors that influence the size of the drops are the mechanical means available for atomization, steam velocities, moisture in the steam, temperature, and the physical properties of the oil.

Oil Feed Atomizers. When oil is delivered by a mechanical or hydrostatic lubricator to the end of a pipe in the steam line, steam chest, or cylinder, it may be in the form of a large drop, or spread out flat over a considerable surface. If the lubricator is located so that the feed pipe remains completely full all the time, at each stroke of the pump a little oil will ooze out at the end of the pipe and will be wiped off and carried away by the steam.

Influence of Steam Characteristics. After the best mechanical atomizing appliances have been provided, and when the oil is fed at the best place for thorough atomization and distribution, it becomes necessary to consider the effect of the properties of the steam and the oil.

Three properties of the steam itself might be expected to have some influence on atomization—pressure, temperature, and moisture.

Steam Pressure. Pressure apparently has no influence upon the size of the drops. The compressibility of oil is too slight for the existing pressure to have any bearing on the size. It may be assumed that, if pressure were the only influence, the size of the drops would be exactly the same in steam at 200-lb, pressure and at 25-in. vacuum. Pressure may have some effect upon the distribution of the oil through the whole volume of the steam, in that when equal quantities of oil are led the quantity of oil per unit weight of steam will be lessened as the steam pressure is increased. This might possibly necessitate the use of more oil per unit volume of high-pressure steam.

Steam Temperature. Temperature, however, has a very decided influence upon the size of the drop, and since high temperatures accompany high pressures, the oil drops carried by high-pressure steam will not be as large as they might be in low-pressure steam. The steam temperature affects the size of the oil drop only because it raises its temperature. Two properties of the oil are affected by heat, its surface tension and viscosity.

Surface Tension. The surface tension of a liquid has been defined as the property which causes the surface to contract into the smallest possible area for a given mass. It is this property that causes drops suspended in a gas or vapor to be round instead of some other shape. A liquid that has a high surface tension will hold a larger weight in a single drop than another liquid with a lower surface tension. This means that an oil having a low surface tension will divide into smaller drops than one having a higher surface tension. Heat reduces the surface tension. Consequently, a high temperature is of greater assistance in the formation of small globules than is a low temperature, and better atomization is secured.

Temperature and Viscosity. Temperature further improves atomization because it reduces the viscosity of the oil. A viscous oil is not so readily atomized as a thin oil; it adheres to the feed pipe and is not so readily blown off. All oils thin out as they are heated, and on this account a high temperature facilitates the mechanical division of the oil into small particles. Experience has taught that a low-viscosity cylinder oil will atomize more quickly and more completely than a high-viscosity cylinder oil.

Moisture Influence Atomization. Moisture in the steam also improves the atomization, because the surface tension of the oil when in contact with water is less than when in contact with dry steam. Consequently, some of the drops that are formed, particularly those in immediate contact with the moisture, will be smaller than if there were no moisture present at all. This effect is entirely different from that of the formation of a globule completely enclosed in water, as the relative densities of oil and water are so close together that a large drop can be formed.

Compounding Improves Atomization. Aside from the viscosity (the viscosity at the steam temperature, not at some other temperature) and the surface tension, there are two other qualities of the oil that have some influence upon atomization. One of these is compounding and the other is filtration, or degree of refinement.

Compounding consists of the addition of an animal oil to the mineral cylinder oil. These animal oils have a lower surface tension than the mineral oil, particularly in the presence of moisture, and when they are in solution, have a tendency to reduce the surface tension of the mixture. They also reduce the viscosity slightly. It would seem that a compounded oil should atomize more readily than a straight mineral oil, and such is probably the case.

(Concluded in April issue)

COMBUSTION TOPICS

A REFRACTORY PRIMER FOR FURNACE ENGINEERS*

Furnace repairs add approximately one dollar to the cost of each ton of steel produced. From the standpoint of design, operation and maintenance, a goodly proportion of our readers are vitally interested in this item of cost. To meet this interest, we start our new department, "Combustion Topics", with a series of informative articles on furnace materials, beginning with the most important item, refractories.

Abrasion: The wearing away of a material at its surface through the cutting action of solids. Refractories are often subjected to the abrasive action of tools, moving charges (such as lumps of lime in a vertical lime kiln), or dust laden gases.

Acid or Acidic Refractories: Refractories which contain an appreciable amount of free silica, that is, silica uncombined chemically with other materials. Silica brick are composed almost entirely of free silica, and are therefore strongly acid; most fireclay brick contain relatively small quantities of free silica, and are therefore somewhat acidic.

Alumina: A chemical compound, the oxide of aluminum; chemical symbol Al_2O_3. Alumina is one of the essential constituents of diaspore, bauxite and clay.

Basic Refractories: Refractories which contain either free magnesite or lime in considerable quanity. Magnesite brick, which is largely composed of uncombined magnesia, is strongly basic.

Bauxite: A mineral theoretically containing about 74 per cent alumina chemically combined with 26 per cent water. The water can be driven off only by heating the material to a relatively high temperature. Commercial bauxites contain variable proportions of silica, iron oxide, titania and other impurities. The purest types are used mainly for the manufacture of aluminum.

Calcination: Many mineral substances when heated to a relatively high temperature lose weight, due to the passing off of some constituent in the form of a gas. Limestone, which loses weight and is converted to lime upon heating, is a familiar example. The heating process is known as calcination. Clays are calcined for the purpose of driving off combined water, and effecting shrinkage.

Chrome Ore: Chromite: A heavy black mineral containing as an essential constituent the oxide of chromium (chemical formula Cr_2O_3).

Chrome Brick: Brick made from chrome ore and usually containing 35 to 44 per cent of chromic oxide.

Clay: "An earthy or stony mineral aggregate consisting essentially of hydrous silicates of alumina, plastic when sufficiently pulverized and wetted, rigid when dry, and vitreous when fired at a sufficiently high temperature."

Corrosion: Gradual wearing away of a solid body through chemical action, as the rusting of iron. Corrosion of furnace linings through chemical attack by slags, coal ash or other fluxes, occurs in many types of furnace practice.

Dead-Burned Magnesite: A sintered product obtained by calcining the mineral magnesite at a high temperature. It consists essentially of magnesia (M_gO), usually with about 15 per cent of other oxides.

Diaspore: A mineral theoretically containing about 85 per cent alumina and 15 per cent water of combination. Commercial diaspore of the purest grade usually contains between 70 and 80 per cent alumina after calcination; the remainder is mainly silica, with small amounts of other oxides.

Diaspore Clay: "A rock consisting essentially of diaspore bonded by fireclay."

Erosion: Wearing away of a solid through removal of loosened particles by mechanical action of a gas or a liquid. In furnace practice, the blowing away by the furnace gases, or washing away by a slag or molten bath, of loosened particles of refractory material from the lining, is called erosion. The sand-blast action of dust-laden gases moving at high velocity, is a combination of abrasion and erosion. The washing away of grog particles from a brick, by a slag, after the bond of the brick has been softened by chemical attack, illustrates the combined action of corrosion and erosion.

Fireclay: "A sedimentary clay of low flux content usually associated with coal measures." Fireclay is the raw material from which fireclay brick are manufactured.

Firebrick: Brick manufactured essentially from refractory fireclays.

Flint Fireclay: A hard or flint-like fireclay with very low plasticity. It usually breaks with a smooth or shell-like fracture.

Flux: A substance or mixture which promotes fusion of a solid material by chemical action. The ash of many coals, and various other materials act as fluxes upon refractories.

Furnace Chrome: Finely ground chrome ore, suitable for laying brick or for patching or daubing in furnaces.

Furnace Magnesite: Finely ground dead-burned magnesite, suitable as a joint material for magnesite brick, and for patching or daubing furnace masonry.

*(Adapted from Harbison-Walker's "Modern Refractory Practice")

Fusion: A state of fluidity or flowing, in consequence of heat; the softening of a solid body, either through heat alone or through heat and the action of a flux, to such a degree that it will no longer support its own weight, but will slump or flow. The term fusion also refers to the union, or blending of materials, such as metals, by melting them together as in the formation of an alloy.

Fusion Point: The temperature at which fusion takes place. Most refractory materials have no definite fusion point, as they soften gradually over a relatively wide range of temperatures. See also Melting Point and Pyrometric Cone Equivalent.

Ganister: A dense, high-silica rock (quartzite), suitable for the manufacture of silica brick. Confusion sometimes results from the use of this term, because it is also applied in some parts of the country to crushed firebrick or to mixtures of either crushed firebrick or silica rock, with clay, for use in tamped linings.

Grain Magnesite: Dead-burned magnesite in granular form, consisting of a mixture of grains varying in size from about ⅝-inch diameter to very minute particles.

High-Alumina Refractories: Refractories containing 50 per cent or more of alumina and made wholly or in part from one of the alumina minerals (diaspore, bauxite, gibbsite, cyanite, sillimanite, andalusite, or others) or fused alumina (artificial corundum).

Kaolinite: A mineral consisting theoretically of 39.8 per cent alumina, 46.3 per cent silica, and 13.9 per cent combined water; chemical formula Al_2O_3 $2SiO_2 2H_2O$; the principal constituent of most fireclays.

Lime: Calcium Oxide, formula CaO; commercially produced by calcination of limestone.

Loss on Ignition: A term used in reporting the results of chemical analysis; the loss in weight which results from bringing a sample of a material to a white heat, after preliminary drying at a temperature just above the boiling point of water. The loss in weight upon drying is called "free moisture"; that which occurs above the boiling point "loss on ignition." The chemically combined water in clays, and the carbon dioxide of limestones, are usually reported in chemical analyses as "loss on ignition."

Magnesite: A mineral consisting of magnesium carbonate and theoretically containing 47.6 per cent magnesia and 52.4 per cent carbon dioxide; chemical formula M_gCO_3. Commercial refractory magnesite contains a small percentage of other oxides, such as lime, silica, alumina, and iron oxide.

Magnesite Brick: Brick consisting essentially of magnesia (M_gO), with usually about 15 per cent of other oxides.

Melting Point: In common speech, the temperature at which a solid changes to the liquid condition; technically the temperature at which the crystalline and amorphous phases of a material coexist in equilibrium. Metals and most crystalline materials have sharp melting points, i.e., they change abruptly from solid to liquid at definite temperatures. Substances such as glass grow more and more plastic as the temperature is raised, and finally become liquid, hence there is no definite temperature at which the transition occurs from a distinctly solid to a distinctly liquid state. Most refractory materials have no true melting points, as they soften gradually over a relatively wide range of temperatures. See also Fusion Point and Pyrometric Cone Equivalent.

Monolithic Lining: A one-piece lining, or lining without joints.

Neutral Refractory: A refractory material which is neither definitely acid nor definitely basic. However, the term is merely relative in most cases, since at high temperatures such a material will usually react chemically with a strong base, functioning as a weak acid; or with a strong acid, functioning as a weak base. Chrome is the most nearly neutral of all the commonly used refractory materials.

Nine Inch Brick: The standard 9" x 4½" x 2½" straight brick; the unit of measurement of brick quantities in the refractories industry. A single shape, a large shipment, and the daily or yearly output of a brick plant may all be expressed in readily understandable figures by reducing them to their "9-inch equivalent."

Permeability: The property of a porous body which permits a gas or a liquid to flow through it. Permeability is measured by the rate of flow of a standard fluid under definite pressure. The permeability of a body is dependent upon the number, size and shape of the interconnecting pores. Pores which are sealed off from those adjoining have no effect upon permeability.

Plastic Fireclay: A fireclay which has sufficient natural plasticity to bond non-plastic materials.

Plasticity: That property of a material as a result of which it can be molded without rupture into any desired form, which is retained after the pressure of molding has been removed. Finely ground clays usually become plastic upon the addition of water.

Pores: Porosity: Refractory bodies are not composed entirely of solid material, for between the solid particles are small voids called "pores." That this is true is evident from the common observation that brick absorb water. The percentage of the total volume of a brick which is taken up by porespace is known as its "porosity."

Pyrometric Cone: One of a series of pyramidal shaped pieces consisting of mineral mixtures, and used for measuring temperature effect. A standard pyrometric cone is a three-sided pyramid; and, depending upon its position in the series, is either 3 inches high by ⅝-inch wide at base, or 25/32-inch high by ⅜-inch wide at base. Each cone is of a definite mineral composition, and has a number stamped upon its side; and when heated under standard conditions, it bends at a definitely known temperature. Pyrometric cones are widely used in controlling the firing temperatures for ceramic materials,

and in determining their relative resistance to high temperatures.

Pyrometric Cone Equivalent (P.C.E.): A term used as an index of the heat-resisting qualities, or refractoriness, of firebrick and other ceramic materials. The determination is made in the following manner:

1. A sample of the material to be tested is pulverized.
2. From the powdered sample are molded "test" cones similar in size and shape to the standard pyrometric cones.
3. A test cone is placed in a suitable furnace with a series of "Standard Cones" and heated at a definite rate until it softens and bends sufficiently for its tip to touch the base. At this temperature it will usually be found that one standard cone has softened to approximately the same extent as the test cone. The number of this standard cone is spoken of as the "Pyrometric Cone Equivalent" of the material being tested.

In the past, the terms "fusion point," "Melting point," and "softening point" were all used rather loosely for what is now called the "Pyrometric Cone Equivalent."

Quartz: A common mineral, consisting of silica (SiO_2). Sea-sands, sandstones and quartzites are composed largely of quartz, which occurs also in numerous other rocks.

Quartzite: A rock consisting essentially of quartz grains so strongly bonded together that when the rock is broken the fracture will pass through both grains and bonding material, instead of between the grains. Quartzite is the basic raw material of the silica refractories industry.

Refractories: Structural materials used at high temperatures in industrial furnaces. While their primary function is resistance to heat, they are usually called upon to resist one or more of the following destructive influences: Abrasion, pressure, corrosion by slags or other fluxes, or rapid changes in temperature.

Silica: A chemical compound, the oxide of silicon; chemical symbol SiO_2. It is one of the most abundant constituents of the earth's crust, as practically all rocks contain silica in some proportion, either free or combined with other materials. Quartz and chalcedony are common silica minerals; quartzite, sandstone and sand are composed largely of free silica in the form of quartz; granite contains abundant silica both free and combined; while clays, kaolins and feldspars contain silica in combination as an essential constituent.

Silica Brick: Brick made from ganister (quartzite), bonded with lime, and consisting essentially of silica, with usually about 2 per cent of lime, and small quantities of iron oxide, alumina and alkalies.

Silica Cement: Silica Clay: Finely ground silica material, used mainly as mortar for laying silica brick.

Spalling: "Breaking or cracking of refractory brick in service, to such an extent that pieces are separated or fall away, leaving new surfaces of the brick exposed."

Spalling is of four types:

(1) Thermal Spalling. The cracking is caused wholly or mainly by rapid expansion or contraction of the brick, as a result of rapid temperature fluctuations.

(2) Textural Spalling. Changes in the texture or in the mineral constitution of the hot end of a brick, due to the action of heat, or to absorption of slags or fluxes, result in the formation of different zones between the inner and outer brick surfaces. The physical properties of these zones may differ not only from those of the original brick, but also from each other. The inner ends of the brick may tend to crack or fall off for various reasons, such as the development of shrinkage cracks; differences in thermal expansion between the inner zone and the next zone; or increased sensitiveness to rapid temperature changes due to vitrification or slag absorption at the hot end of the brick.

(3) Mechanical Spalling. Shattering of brickwork is often due to such influences as abuse in removal of clinker and slag, "pinching" (due to thermal expansion), and other causes. "Pinch spalling" in sprung arches is frequently observed and results from the thermal expansion of the heated portions of the brick and the consequent transfer of the arch stresses to a relatively small bearing surface at the hot end.

(4) Structural Spalling. Improper design of the brick shapes, faulty design or construction of the furnace, or excessive insulation increasing unnecessarily the severity of furnace conditions, may be directly responsible for spalling of any of the three types above described.

In furnace practice, spalling may be either simple or compound, dependent upon whether one or more of the various types are involved. For example, it may result from the combined action of rapid temperature fluctuations (thermal spalling), and vitrification of the hot end of the brick (textural spalling).

Slag: A substance formed by fusion, in one of several ways:

(1) In smelting operations, through the combination of a flux, such as limestone, with the gangue or waste portion of the ore.

(2) In refining of metals, by substances (such as lime) added for the purpose of effecting aid in the refining.

(3) By the action of fluxes, such as coal ash, upon refractories.

Slags after cooling are usually hard and rock-like. They are generally waste products, although the slags of some industries form valuable by-products.

Specific Gravity: The ratio of the weight of a substance to that of an equal volume of water. Since the weight of a cubic inch of water is .578 ounces, it follows that the weight of a cubic inch of the substance, in ounces, divided by .578 is its specific gravity.

The total volume of a brick is made up of two parts: first, the solid material, and second, the pore space. The specific gravity of a brick may be expressed in two or more ways. The weight of the

solid material excluding all pores, in ounces per cubic inch, divided by .578 is the true specific gravity. The weight of the specimen as a whole (solid material with all its included pores), in ounces per cubic inch, divided by .578, gives the **Bulk or Volume Specific Gravity.**

The apparent specific gravity is the specific gravity of the solid material plus the sealed pores, or pores not permeable to water.

Thermal Conductivity: The flow of heat energy through particles of matter in contact. For engineering purposes, thermal conductivity is measured by the quantity of heat expressed in B.T.U.'s which will flow in one hour through a square foot of wall one inch thick, for each degree Fahrenheit difference in temperature between the two sides of the wall.

Thermal Expansion: The increase in volume shown by practically all materials when heated. Such expansion is of a temporary character, as the body returns to its original dimensions when cooled. Thermal expansion is not to be confused with volume changes of a permanent character which many materials undergo when heated.

Vitrification: A process of permanent chemical and physical change in a ceramic body, such as a fireclay, at high temperatures; the most noticeable effect is reduction in porosity. Most fireclay refractories have a measurable porosity and a dull appearance on broken edges. After complete vitrification, through exposure to an extremely high temperature, fireclay brick are very strong but brittle, the pores have almost entirely closed, and pieces of brick are usually shiny or glassy in appearance.

W. A. Irvin Selected As President of The United States Steel Corporation

William A. Irvin was selected on March 9, to succeed James A. Farrell as president of the United States Steel Corporation when Mr. Farrell retires on April 18. Four months before Mr. Farrell's retirement was announced, Mr. Irvin was promoted from the vice presidency of the American Sheet & Tin Plate Company to the post of vice president in charge of operations for the Corporation.

Although his career in steel began 37 years ago, Mr. Irvin who is 58 is one of the youngest men ever to head the United States Steel Corporation.

He was born in Indiana, Pa., and when only 11 years old began work as a telegraph messenger boy. In 1888 he entered the employ of the Pennsylvania Railroad as a telegraph operator and he had been advanced to passenger agent when in 1895 he left the railroad to take a position as shipping clerk with the P. H. Laufmann Company, Limited, manufacturers of sheet and tin plate, of Apollo, Pa. In 5 years he had risen to superintendent of the Laufmann plant and when it was taken over by the American Sheet Steel Company he was transferred to the general offices of this company in New York.

In 1904 when the American Sheet Steel Company and the American Sheet & Tin Plate Company were merged Mr. Irvin was brought back to Pittsburgh as operating vice president of the American Sheet and Tin Plate. He remained in Pittsburgh until September, 1931, when he was promoted from vice president of the American Sheet & Tin Plate Company to vice president of the Corporation.

The Association of Iron and Steel Electrical Engineers extends their congratulations and best wishes for the continued success of Mr. Irvin, one of the best known of operating men in the Industry. His climb from a telegraph messenger boy to the head of the United States Steel Corporation is one of inspiration and encouragement to every man in our vast Industry.

ASSOCIATION NOTES

The Association of Iron and Steel Electrical Engineers will hold its 28th Convention in Pittsburgh, Pa., June 20-23, 1932. The decision to hold a Convention and Exposition was reached after careful consideration by the Board of Directors of the A. I. & S. E. E.

The paragraph below also reflects an attitude of optimism and courage. From present indications the June Convention of the A. I. & S. E. E. will be well attended and the Iron and Steel Exposition will present many new developments in Steel Mill Equipment of vital interest to the engineers of the Iron and Steel Industry.

"Talk of curtailing or modifying the annual convention of the National Electric Light Association has been abandoned, and preparations for the great gathering at Atlantic City on June 6 to 10, with the concurrent manufacturing exhibition, will soon be in full swing at headquarters. It has become the conviction of N. E. L. A. officers that vigorous meetings and crowded exhibits are even more important in a time of business depression than in a period of full prosperity. President J. F. Owens is emphatically of this opinion and has officially declared his belief that a normal attendance can confidently be expected and that no thought of abandoning a complete exhibition should be entertained."

ITEMS OF INTEREST

PERSONNEL CHANGES

R. H. Grove, for a number of years chief engineer of the Apollo Steel Company, Apollo, Pa., has resigned, effective March 1. He plans to do some development and experimental work and then engage in business for himself.

L. M. Johnston, formerly vice president of the A. M. Byers Company, Pittsburgh, has been elected president of the Keystone Driller Company, Beaver Falls, Pa., drilling equipment manufacturer.

E. C. Rebeske, formerly treasurer and secretary of the Union Drawn Steel Company, Beaver Falls, Pa., a subsidiary of Republic Steel Corporation, Youngstown, O., has been elected vice president of the Keystone company. Other officers elected are R. R. Downie, secretary, and C. T. Smith, treasurer.

Effective March 1, 1932, the Clark Controller Company and allied interests, the Sundh Electric Company of Newark, N. J., and Una Welding, Inc., of Cleveland, O., will be represented in St. Louis and surrounding territory by David O. Stewart, 619 Bank of Commerce Building, St. Louis, Mo.

C. E. Anderson has been appointed auditor of disbursements in the accounting department of the General Electric Company to succeed the late F. D. Kamerer, it has been announced by S. L. Whitestone, comptroller of the company.

WITH THE MANUFACTURERS

The Allis Chalmers Manufacturing Company of Milwaukee, Wis., are now distributing their Bulletin No. 3016 on "Transformers and Their Applications." Copy of this bulletin may be obtained by writing the above company.

United Engineering & Foundry Company of Pittsburgh have prepared their latest "United Bulletin R-1001-Roll List." This bulletin contains 16 pages and is well illustrated. Copies may be obtained by writing the above company.

The American Air Filter Company, Inc., Louisville, Ky., have just prepared a booklet the first of a new series of literature dealing with the applications of air filters. The booklet entitled "Filtered Air—Its Importance in Building Ventilation and Air Conditioning" is designed primarily for executives who have much to say about the equipment going into buildings and are interested in the matter of air pollution and its elimination. The second booklet of the series is entitled "Filtered Air in Industry," will be ready for distribution in the near future.

The Michigan Welding Supply Corporation, Muskegon, Mich., are now distributing a four-page bulletin on the Magno-Matic Eye Shield. The bulletin is well illustrated and interested parties may secure the bulletin by writing the above company.

Copies of the latest Elliott Company bulletins H-7 and J-4 are now ready for distribution.

Bulletin H-7 is devoted to Elliott steam turbine-generators, setting forth design and construction details of the latest type Elliott turbine-generator units, with large sectional view and detail pictures. There is a section on "Turbine Efficiency" with a total heat-entropy diagram, chart of overall efficiencies, etc. Numerous installation pictures are presented.

Bulletin J-4 describes Elliott commutating pole direct current motors and generators and describes these machines with particular comment on armature windings, double section commutator construction, etc.

Copies of these publications may be had upon request to Elliott Company General Sales Offices at Jeannette, Pa., on the steam turbines, and at Ridgway, Pa., on commutating pole machines or to any of the Elliott Company district offices located in the principal cities.

Two Freyn-Design Electric Roll Heaters have been purchased by the Worth Steel Company, Claymont, Delaware, from Freyn Engineering Company, Chicago. This installation makes a total of 326 Freyn-Design Electric Roll Heaters in service for preheating sheet and tin mill rolls.

Century Electric Co., St. Louis, Mo., Type R. Direct Current Motors for vertical operation are designed to meet the many requirements of vertical motors.

They are ball bearing, grease-lubricated, mounted on a ring base or directly on the driven equipment, as required.

The top bearing bracket is protected with a cover and may be furnished either open or with screen or solid covers to meet surrounding conditions; built in sizes from 1 to 150 horsepower.

The Century line of slip ring motors has been extended from 20 horsepower to 250 horsepower, 1800 RPM, 60 cycle. The complete line now extends from ¼ to 250 horsepower.

LIGHTNING TESTS LEAVES TRANSFORMERS UNHARMED

Lightning flashes of 1,500,000 volts proved harmless to the de-ion equipped distribution transformer developed by the Westinghouse Electric & Manufacturing Company in a demonstration test witnessed by executives, operating managers and en-

gineers representing electrical power companies of Pennsylvania and Ohio.

Continuity of electric service, even during severe lightning storms, is assured with this new transformer. Engineers working for years on this difficult problem have now found its solution. When lightning strikes this transformer, it jumps an ingeniously devised gap, bi-passing the working parts and preventing disruption of service.

The tests were conducted in the Westinghouse High Voltage laboratory, Sharon, Pa., which is capable of generating 3,000,000 volts, the largest man-made lightning flashes of that kind in the world. One transformer was subjected to 175 strokes of this artificial lightning. At the completion of the tests, it was undamaged and unmarked, yet the test reproduced in a few hours the wear and tear normally met in many years of service.

H. V. Putman, engineering manager of the Westinghouse plant was in charge of the tests. He was assisted by J. K. Hodnette who developed this new lightning-proof distribution transformer, the first application of the de-ion arc-quenching principle to transformers.

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THYRATON TUBES NOW GOVERN SPEED OF INTERMITTENT LINE AND SPOT WELDING

Close and accurate control of the frequency of current interruption in line welding, and an increase in speed of interruption up to 1800 per minute, are among the advantages of a new type of Thyratron tube timing control announced by the General Electric Company. The new control replaces mechanical interrupters.

The equipment operates in synchronism with the alternating current supply of the welding machine. The weld is always started at a predetermined point in the voltage wave and stopped when the current passes through zero. Thus the period of current application can be accurately controlled even with "on" times of but one or two cycles.

The new synchronous tube timer supplements, and is designed to work in conjunction with, the General Electric welding control type CR 7503 recently announced which uses Thyratron tubes instead of contactors for interrupting the flow of current. By a combination of the two equipments, a very close degree of accuracy and a high welding speed are obtained.

The control embodies a series transformer the primary of which is connected in series with the primary of the welding transformer and the secondary of which is short circuited by two Thyratron tubes connected thereto. Welding current will not flow unless the grids of these tubes are properly energized. For controlling and energizing the grids of these Thyratrons three small Thyratron tubes are used. One in combination with a condenser acts as a timer. This timing Thyratron trips when the condenser is charged to a certain point and controls the grids of the other two small Thyratrons which, in turn, control the two power Thyratrons. The control has no moving parts and is subject to no such wear as is involved in mechanical interrupters.

WALKING BEAM FURNACES

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Surface Combustion Corporation has contracted to install two continuous walking beam furnaces for heating packs and pairs in the Aliquippa Tin Mills of Jones and Laughlin Steel Corporation. These furnaces differ from any built previously in two major respects. The first is that each furnace has three conveyors. Secondly, each conveyor is driven entirely independent by power delivered through a common pump, the driving mechanism and control being a specially developed hydraulic system adapted to extremely rapid operation. A standard Surface Combustion chain type discharge (patent applied for) is used on each conveyor.

The furnaces are over and under fired using coke oven gas with special provision for maintaining a smoky atmosphere.

Announcement is also made of the closing of a contract for another walking beam type pack furnace for The Tennessee Coal, Iron and Railroad Company at Birmingham, Alabama. This furnace is the tenth one of its kind built for this company. It will be fifty five feet in length and will have a double row of work and over and under firing with natural gas systems of premix and diffusion burners. The standard Surface Combustion chain type discharge (patent applied for) is incorporated.

Youngstown Sheet and Tube Company has contracted with Surface Combustion Corporation for a walking beam tin plate normalizing furnace to be installed in the Indiana Harbor Works. The inside dimensions of the furnace will be 6 by 60 feet and it will operate on low pressure coke oven gas.

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PUNCH PRESS MOTORS

Reliance Electric & Engineering Co., 1088 Ivanhoe Road, Cleveland, Ohio, have developed a line of induction motors especially adapted for punch presses and machinery with similar operating characteristics. These range in size from ¾ hp. to 200 hp.

The chief advantages of Reliance Punch Press Motors are that the installation and operating costs are lower and the power factor is considerably improved. A much smaller motor can be used resulting in power savings which for many applications amount to as much as half that required for ordinary induction motors.

In the design of these motors the fly wheel with which all punch presses are equipped was especially considered. During the unproductive part of the operating cycle they deliver power to the fly wheel. When work is being done they slip and permit the fly wheel to carry the brunt of the load.

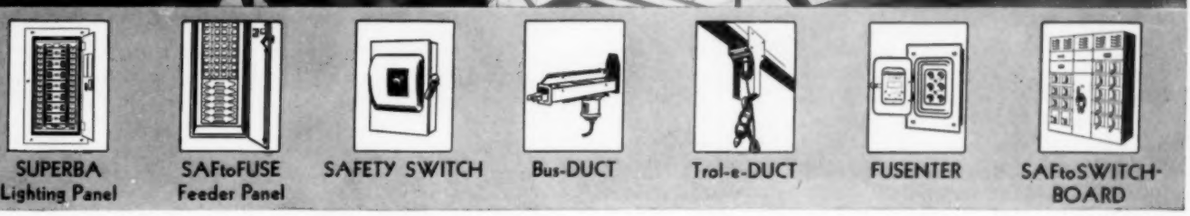
These motors develop a starting torque of approximately 225% and have a slip of 8 to 12%. Normal starting current is required.

The frame is strong and rigid, being fabricated from bar steel electrically welded. Insulation is thorough and of highest quality. Large conduit outlets are provided which make connecting easy.

Reliance Punch Press Motors are furnished with either ball or sleeve bearings and may be obtained either in open, fully-enclosed or fully-enclosed fan-cooled construction.

"Here's the Best Investment in Efficiency We've Ever Made!

This Bull Dog Electrical Distribution System..."



Put BULL DOG on the Job

In this big Carburetor Plant (name on request) the connection from 4 banks of Transformers to 2 sets of Lighting and Power Switchboards is made with Bull Dog Bus-DUCT of 2000 Amp and 1500 Amp capacity.

Two 600 ft. runs of 1500 Amp and 1000 Amp Bus-DUCT then connect the 2 Power and 2 Lighting Switchboards within the Plant. Use of Expansion Joints in these long runs of Bus-DUCT is a unique feature.

Distribution to Branch Circuits is made with Bull Dog Pro-DUCT and SAFtoFUSE Feeder Panels having convertible and interchangeable provisions, to meet the future changes or expansions.

BULL DOG modern Electrical Distribution Systems are Flexible, Mobile and 100% Salvageable. Write for catalog.

BULL DOG ELECTRIC PRODUCTS COMPANY
DETROIT, MICHIGAN

OVER 25 YEARS OF RESEARCH AND DEVELOPMENT

WORLD'S FIRST ANTI-FRICTION LOCOMOTIVE COMPLETES 100,000 MILE TEST

After operating on fourteen different railroads since it was put in service in April, 1930, the first locomotive ever to be equipped with anti-friction bearings recently pulled into the Seattle Terminal of the Northern Pacific Railroad at the termination of the run which completed its initial test period of 100,000 miles.

The locomotive is equipped with Timken Tapered Roller Bearings in all axles—engine truck, driver axles, trailer truck and tender trucks. During this test period it operated from coast to coast under every conceivable condition of climate, temperature, terrain, and trackage, hauling the heaviest freight trains and the fastest passenger trains. It was in service on the New York Central; Pennsylvania; Chesapeake & Ohio; Erie; New York, New Haven & Hartford; Boston & Maine; Delaware & Hudson; D. L. & W.; Lehigh Valley; Nickel Plate; Chicago & Alton; Missouri Pacific; Chicago, Burlington & Quincy, and the Northern Pacific.

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NEW TUBE TIMING CONTROL FOR WELDING SERVICE

Cutler-Hammer, Inc., 259 North Twelfth Street, Milwaukee, Wis., manufacturers of electric control equipment, announces a new device which promises wide use in industry. The product is a new timing device for spot, projection and other forms of resistance welders. The manufacturer claims extremely accurate timing control of the welding operation. Use of an electronic tube, it is further stated, makes possible an accuracy of better than a fraction of a second and the device has an adjustable range up to 16 seconds.

This new Tube Timing Welder Control described in Bulletin 13101 is said to eliminate all guesswork on the operator's part—enabling unskilled operators to produce successful welds and to practically eliminate rejects and throw-outs. The timing is adjusted by a knob inside the enclosing case. This new Tube Timing Control requires a very small mounting space and operates on 110 to 550 volts A.C., 25 to 60 cycles. Vibration, severe or intermittent service will not affect the accuracy of this control, the manufacturer asserts.

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CENTRIFUGAL PUMPS FOR HANDLING HOT OR COLD ACID

Allis-Chalmers Manufacturing Company, Milwaukee, Wis., is building a new pump for handling acids in process work. It is of the single suction type and all parts coming in contact with the acid pumped are made of **chrome steel.** To insure uniform expansion from the center of the pump when handling acids of high temperature, the casing is supported on the horizontal center line by brackets and it is also keyed on the vertical center line underneath the water cooled stuffing box.

The pump is so constructed that the rotating element including the self-aligning, anti-friction, bearings and the Falk coupling can be removed through the suction end of the pump without disconnecting the discharge piping or casing brackets or disturbing the motor.

Tests of these pumps show very high efficiency and quiet operation.

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OBITUARIES

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R. H. Crevoisie, Jr., 48, an active member of the A. I. & S. E. E., died at the Sewickley Hospital, February 28. Mr. Crevoisie was born in Garrettsville, Ohio. He was educated in the public schools of Canton, Ohio, Rose Polytechnic Institute and the Case School of Applied Science, Cleveland, Ohio.

R. H. CREVOISIE, JR.

At the time of his death Mr. Crevoisie was Chief Engineer of the A. M. Byers Company. Previous to his joining the A. M. Byers Company he was associated in an engineering capacity with the Republic Steel Corporation, Youngstown Sheet & Tube Company and the Morgan Engineering Company.

Mr. Crevoisie was well known throughout the Iron and Steel Industry and his sudden death comes as a severe shock to his many friends. The membership of the A. I. & S. E. E. extend their sympathies and condolences to the family of this prominent engineer.

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John T. Harrington, formerly president of the Trumbull Steel Co., died on February 28 in Sydney, Australia, while on a world tour. He had been identified for many years with the iron and steel industry of the Mahoning Valley in an advisory capacity.

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John O. Horning, vice-president and treasurer of the Mesta Machine Co., West Homestead, Pa., died at Rochester, Minn., on February 13.

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John W. Galvin, aged 84, well known as an open-hearth steel expert and for 30 years open-hearth superintendent of the Inland Steel Co., Chicago, died at Long Beach, Calif., February 17.